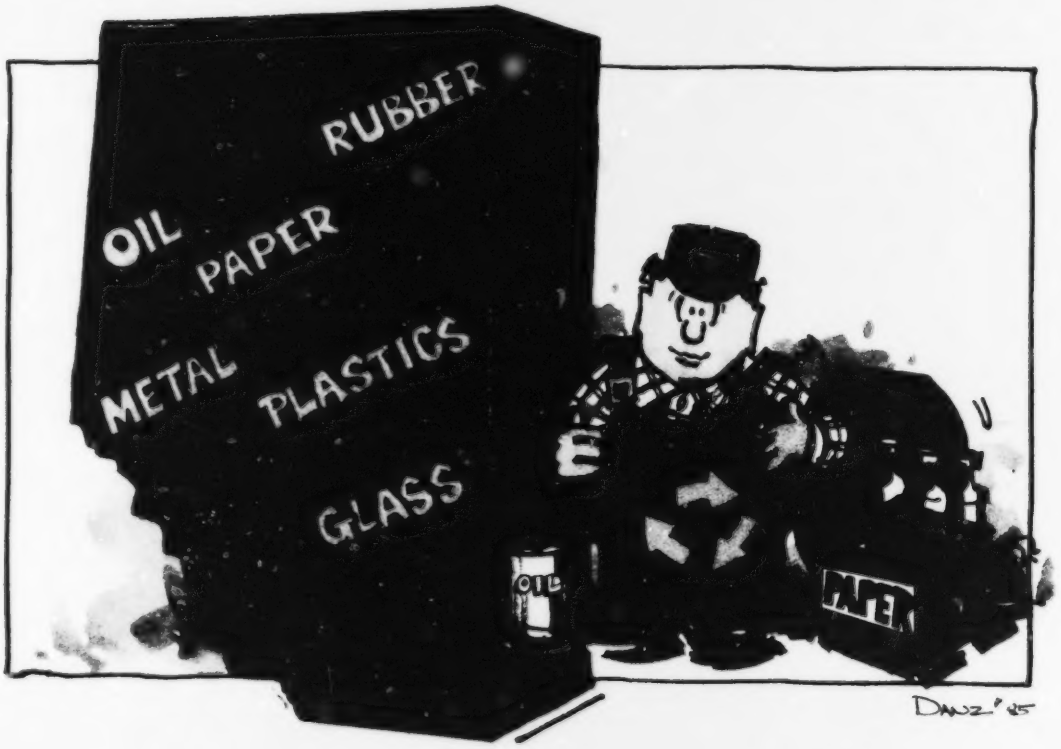
RESOURCE RECYCLING

IN ALBERTA



Alberta

ENVIRONMENT COUNCIL OF ALBERTA

86-1295/

Terms of Reference

FOR PUBLIC HEARINGS ON THE RECYCLING OF WASTE WITHIN THE PROVINCE OF ALBERTA

The Environment Council of Alberta is hereby requested to:

1) Enquire into the potential for the economic recycling of products presently disposed of as wastes; giving particular attention to:

   a) the potential, scope and obstacles to increased recycling by private sector business enterprises;

   b) the potential, scope and obstacles to increased recycling by volunteer organizations;

   c) the support role of local governments and the provincial government in facilitating recycling by the private sector and volunteer organizations, considering the potential reduction in waste disposal costs, the enhancement of the environment and privatization.

2) Consider the potential and comparative economics of the generation of energy from wastes when the alternative of the creation of useful goods and services from wastes is not feasible.

3) Hold public hearings at suitable locations throughout the province, and report to the Minister of Environment and the Lieutenant-Governor in Council on completion of the report.

— Order In Council 106/85

RESOURCE RECYCLING IN ALBERTA

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Preface

The Government of Alberta has asked the Environment Council of Alberta to enquire into the potential for the economic recycling of products presently disposed of as wastes and to consider the potential and comparative economics of the generation of energy from wastes when alternative recycling routes are not feasible. The Environment Council is also to hold public hearings on recycling throughout the province. The Terms of Reference for these hearings are printed on the inside of the cover of this report. Following the enquiry and the public hearings, the Environment Council will submit its report and recommendations to the Lieutenant-Governor in Council.

As part of its preparation for the public hearings, the Environment Council has prepared a series of reports on various aspects of recycling. These reports are intended to provide general background information, to highlight issues the authors believe to be important to the Environment Council's enquiry and public hearings, and to stimulate comment and suggestions from the public to the Hearing Panel. The reports are not intended to provide answers to all concerns about recycling, nor to make recommendations for future actions. Recommendations will be developed by the Environment Council's Public Hearing Panel at the conclusion of their enquiries and the public hearings.

This report provides information on the present status of recycling of a number of materials in Alberta. The report is based on available written information and on communication with persons involved in recycling in Alberta. The report attempts to compile this information into an overview of recycling in Alberta. Unfortunately, there is room for substantial improvement in the collection of data on all aspects of recycling, and the data necessary to present a comprehensive discussion for many of the materials are not available. In particular, data specific to Alberta often are sparse, lacking, or out of date. It is beyond the scope of this report to collect and analyze original data. Therefore, it is not possible to provide the same level of detail in the discussion of each material. In cases where provincial data are sparse, information at a national or regional level may be presented.

Following information about the materials, the amount used, and present recycling activities, the report briefly presents some of the factors that affect increased recycling. This discussion is not intended to be encyclopedic or in depth; it is intended to highlight some of the opportunities and constraints that must be considered during development of a recycling plan for Alberta. Readers are encouraged to bring their experience, concerns, opinions, and their recommendations to the Environment Council of Alberta's Public Hearings on Recycling. The Environment Council needs and requests your input. Your ideas and suggestions are an important part of the process of developing future direction and policies that will aid in enhancing recycling, and thus reduce the burden of waste management while recovering recyclable materials that can support economic development in the province.

Contents

Preface iii

Introduction 1

Metals 3
1. The Resource 3
2. Recycling 3
   Ferrous Metals 5
   Non-Ferrous Metals 8
3. Problems and Opportunities 9
References 10

Rubber 12
1. The Resource 12
2. Recycling 14
   Recycling Pathways 14
   Materials Available 16
3. Problems and Opportunities 18
References 20

Glass 22
1. The Resource 22
2. Recycling 24
   Recycling Pathways 24
   Materials Available 25
   Present Use 26
3. Problems and Opportunities 27
References 28

Lubricating Oil 30
1. The Resource 30
2. Recycling 30
   Recycling Pathways 30
   Materials Available 31
   Present Use 32
3. Problems and Opportunities 34
References 35

Plastics 37
1. The Resource 37
Thermoplastics 37
Thermosetting Resins 38
Quantities and Values 38
2. Recycling 38
Recycling Pathways 38
Present Use 40
3. Problems and Opportunities 43
References 45

Paper 47
1. The Resource 47
2. Recycling 47
Recycling Pathways 47
Present Use 48
3. Problems and Opportunities 57
References 59

TABLES

1. Metal Recycling in Alberta 6
2. Consumption of Rubber Polymers in Rubber Fabrication, 1975 13
3. Applications of Rubber in Canada, 1975 14
4. Waste and Scrap Rubber Generated in Canada During the Production of Goods, by Polymer Type 15
5. Consumption of Glass Containers by Canadian Industry 22
6. Container Glass Recipe for Soda-Lime Flint Glass 23
7. Percentage Composition of Glass in Alberta's Municipal Waste 25
8. Final Disposition of Waste Oils in Alberta, 1973 33
9. Waste Oil Disposal Practices of "Do-It-Yourself" Oil Changers in Urban Areas 33
10. Amounts and Fate of Scrap Plastics Produced by Manufacturing Plastic Products in Alberta 41
11. Waste Paper Demanded by the Canadian Pulp and Paper Industry 50
12. Waste Paper Demanded by All Users in Canada 51
13. Waste Paper Recovered in Canada 52
14. Imports of Waste Paper 54
15. Typical Paper Stock Prices 56

INTRODUCTION

Every day thousands of tonnes of materials are used to produce goods for use in Alberta or for export. In this production of goods, a substantial amount of solid waste (goods and materials not usable by the originator) is generated. This waste can be disposed of through municipal landfill systems. But it can also be disposed of through conversion to energy, dissipated to the environment as liquid or airborne effluent, utilized as a soil additive after composting, or recycled for use in the same or different products. For example, in the brewing industry, the spent grain is recycled as animal feed, while the bottles, cans, and cartons are recycled as reusable bottles, resmeltered cans, and waste paper. Each waste product has a different level of recyclability, with virtually 100 percent of the spent grain being recycled, most of the bottles being reused, and a substantial proportion of the cans and cartons being recovered. Almost none of the bottle caps are reused.

Recycling* occurs at all levels of the economy, from individuals to offices, retail stores, and industry. These activities are not limited to the reuse of material for production of the same product. Recycling may be the reuse of refillable beverage containers, the re-refining of used lube oil, the conversion of glass bottles into beads or plastic bottles into fiberfill, or the treatment of mixed wastes to recover chemicals or heat. The diverse nature of recycling in Alberta is shown in examples such as: bottles returned by individuals for reuse, supermarkets selling baled corrugated containers to paperstock dealers, an Alberta steel industry entirely dependent on scrap steel, office recovery of computer paper, oil collection at the local garage, and the reuse of scrap in the raw material mix. Despite these efforts, substantial volumes of recyclable materials find their way into Alberta's municipal waste management systems or other disposal routes. If left untreated, these materials can create environmental or health concerns, but their appropriate disposal can be very costly. The disposal of materials in landfills, since it leaves materials in an extremely mixed form, makes reuse very difficult and has the potential to waste valuable resources.

This report presents information about the recycling of six commodities: metals, rubber, glass, lubricating oil, plastics, and paper. The report is based on information available from a variety of sources, but concentrates on information relevant to Alberta. Each

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*Recycling is used in this report in a general sense to cover the entire scope of resource recycling from the use of refillable containers to the extraction of components of a material as chemicals or as energy content.

chapter describes the resource, the status of recycling, recycling processes, and possible alternative pathways. These are followed by a section highlighting some of the opportunities and constraints that affect the future of recycling for each commodity.

Comprehensive data on production rates, waste generation, or recovery rates of recyclable materials is often non-existent or difficult to obtain. This affects the discussion of some commodities and highlights an important requirement for better planning in the future. However, the purpose of the report is not to provide a treatise on recycling in Alberta, but to increase awareness of our present recycling activities, opportunities that exist to expand recycling, and some of the constraints to recycling. Through this increased awareness, the reader may more effectively participate in future activities related to resource conservation and materials recycling.

What is the status of recycling in Alberta? Can present recycling efforts be improved? What opportunities exist and what are the constraints? These are the questions this report tries to answer.

METALS

1. THE RESOURCE

Metals can be broadly classified into two groups: ferrous and non-ferrous. Ferrous metals are those in which iron is a major component. The basic characteristic that sets the ferrous metals apart is that they are attracted to magnets.

Non-ferrous metals — those that are not attracted to magnets -- include aluminum, copper, brass, silver, and gold.

Metal products are ubiquitous. However, there are no metal mines in Alberta. All metal milling or fabricating within the province depends on the import of metal or the use of scrap. This affects the type of metal fabricating done in the province and limits it to products for which the economic penalty of transportation costs works to favor the local manufacturer over the out-of-province competitor. If supplies of metal can be made available locally through recycling, a significant portion of the transportation costs can be avoided and the competitive edge of local metal fabricators will be increased.

Recycling of metals is a huge industry world-wide. For example, Chandler (1984) reported that world trade in ferrous metal scrap in 1980 was worth $11 billion (U.S.) and trade in aluminum scrap was worth $600 million (U.S.).

2. RECYCLING

It is useful to begin with some definitions of scrap sources. As with many materials, a distinction is generally made between scrap produced by industrial users and that produced by the general population. In the metal trade, these are called "industrial scrap" and "obsolete" or "post-consumer scrap" respectively.

Industrial scrap can be broken down into two subcategories: "home scrap" and "prompt scrap." Home scrap is scrap that is a direct non-product output of metal production (Beak 1977). It is of known composition and normally is immediately reused in the production plant as part of the feedstock. Prompt scrap is industrial scrap available from outside the metal production plant. It can be defined as non-product metal resulting from manufacturing or fabricating operations (Beak 1977) and includes trimmings, shavings, and

punch outs. It is called prompt scrap because it is usually returned quickly to a metal production facility for reuse. Most manufacturing or fabricating operations with significant volumes of scrap have an arrangement with a scrap dealer for purchase and removal of their scrap. In Alberta, this is generally truer for ferrous metals than for non-ferrous metals. The processing industry for non-ferrous scrap is limited in Alberta and much prompt scrap is either exported from the province or simply enters the next category of scrap: obsolete scrap.

Scrap metal produced by the general population is called "obsolete scrap" or "post-consumer scrap." Beak (1977) defines obsolete scrap as used metal available outside of the normal industrial flow. It is usually metal that has been used and discarded, or is available in obsolete or discarded manufactured or fabricated goods.

An important consideration in recycling of metallic waste is the method of calculating the availability of obsolete scrap. There is often a significant time lag between the primary production of a metal and its availability as obsolete scrap. Industrial scrap is available within a short time after the initial production. The availability of obsolete scrap depends on product life expectancy. Automobiles, for example, have a life expectancy of about 10 years from production to metal recovery. Appliances may have a life expectancy of 15 years, and construction materials may not be available for 40 or more years, while the metal from containers may be available in one year or less. The time lag between metal product fabrication and the availability of metal scrap is particularly important in planning metal recovery programs, since current inventories depend on production in past years and on a product's life expectancy.

There are no primary producers of metals in Alberta and the used metal industry is small. According to Beak (1977), the used metal industry in 1977 consisted of two steel foundries, eight iron foundries, two steel mills, three secondary metal processors, and numerous scrap dealers. The mills, foundries, and processors depend entirely on scrap for their operations, and producers in western Canada are scrap-deficient. Scrap must be imported from eastern Canada and from the United States to satisfy the needs of local users.

For example, production at the Stelco mill in Edmonton is about 293,000 tonnes of steel per year (Bishop n.d.). This level of production requires 315,000 tonnes of scrap per year. The mill has two electric furnaces and produces a variety of bar products: rounds, flats, and angles as well as reinforcing bar. Scrap is purchased primarily from scrap dealers, although Stelco does bid directly on the very desirable railway scrap. All ferrous scrap, whether carbon steel or alloy, is accepted, but the facility cannot accept any cast material or material contaminated with oil, tar, rubber, insulation material, or more than trace amounts of other metals. These contaminants increase stack effluent loadings, overload pollution control equipment, and adversely affect product quality.

Oil, for example, may release sulphur into the molten steel and is not an acceptable contaminant. Tin reduces ductility and impact strength. Copper together with tin induces edge cracking in hot rolling and requires costly additives to remove. Lead erodes expensive furnace refractories. Aluminum oxidizes furnace liners. Therefore upper limits must be placed on the presence of these and other contaminants. Other steel products demand even stricter specification, and one of the major problems facing the scrap metal industry is its ability to provide scrap of high quality and purity to steel manufacturers.

The IPSCO steel mill in Regina also depends entirely on scrap as raw material for its steel. In a good year, the company will process about 540,000 tonnes of scrap. Only 50 percent of this scrap comes from within western Canada; the rest is imported from as far away as Buffalo, New York and Sorel, Quebec. The scrap from within the region is approximately 50 percent railway scrap, 20 percent auto scrap, 20 percent farm scrap, and 10 percent industrial scrap. Scrap purchased from outside the region is 60 percent farm scrap and 40 percent industrial scrap (Backman n.d.).

In 1977, Beak (1977) studied the existing and potential metal recycling industry in Alberta. Much of the information used here is drawn from that report because no more recent comprehensive studies have been conducted. Because of the small size of the industry, Beak (1977) found a reluctance to provide detailed information; hence the numbers discussed below should be considered as approximations.

Table 1 provides information on the amount of used metals available in Alberta and the utilization of that scrap as estimated in 1977.

Ferrous Metals

Ferrous scrap figures were supplied by the steel mills and iron foundries. The figures are an estimate of both home and prompt scrap. The data show that all available scrap is used, but provides no indication as to the proportion of industrial scrap that is collected or made available. Since recovery rates generally are high for industrial ferrous scrap, there may be little room for improvement; however, more complete information is needed.

Automotive scrap was calculated at 50,400 tonnes per year based on automobile registrations and vehicle age. It was assumed that the increasing numbers of cars would offset reduction in scrap production caused by the decreasing average vehicle weight and changes in material use.

Because of the number and availability of automobile hulks, as well as past government programs subsidizing auto hulk recovery in rural areas for aesthetic reasons, automobile scrap metal recycling is a well-established industry. A large auto scrap dealer in western Canada is General Scrap and Car Shredder Ltd. The company operates scrap metal recycling facilities throughout western Canada and it has auto shredders in Calgary and Winnipeg (Lazareck n.d.). According to Lazareck, in spite of perceptions, few large concentrations of auto hulks remain. What is seen in scrap yards is mainly the annual generation of auto scrap awaiting processing.

As well as supplying its own shredding facilities, General Scrap and Car Shredder Ltd. delivers feedstock directly to shredders operated by steel mills in Edmonton and Regina. Shredding of the auto hulk is necessary to facilitate separation of materials. The main materials separated are ferrous metals, non-ferrous metals, rubber, plastics, and upholstery fluff. Shredded ferrous metals are sold to steel mills, non-ferrous metals are separated and exported, and the rest is landfilled. Information collected by Beak (1977) from scrap dealers indicated that 20,200 tonnes per year of usable ferrous scrap were being recovered from car hulks in 1977 through facilities in Calgary and Regina.

Table 1. Metal Recycling in Alberta

	Calgary Area tonnes/year		Edmonton Area tonnes/year		Alberta tonnes/year	
	Available	Recovered	Available	Recovered	Available	Recovered
Industrial Ferrous Scrap (incl. steel, cast, etc.)	45,800	45,800	153,000	153,000	198,800	198,800
Automotive Scrap (ferrous only)	–	12,200	–	8,000 (To Sask.)	50,400	20,200
Appliance Scrap (ferrous only)	–	–	–	–	11,300	–
Beverage Container Scrap (all metal components)	1,080	705	1,220	795	2,300	1,500
Municipal Solid Waste Metal (all metals)	30,200[1]	–	45,000[2]	–	108,000	–
Nonferrous Metals (estimated)	–	–	–	–	63,000	400

Source: Beak 1977

[1] City of Calgary only
[2] City of Edmonton only

Calculations of appliance scrap by Beak (1977) assumed that 1.75 million major appliances were in use in 1977 in Alberta and that 140,000 were discarded each year. The discarded appliances were estimated to contain about 11,300 tonnes of metal. The information presented in Table 1 shows that there is no measurable recycling of appliance scrap. While it is feasible to establish a metals or "white goods" compound at a landfill, this is not often done and the materials are landfilled with the rest of the waste stream. According to Lazareck (n.d.), landfilling large appliances creates problems for compacting equipment. Removal of these materials from the waste stream would save landfill space and reduce equipment wear. Beak (1977) suggested that, if proper shredding facilities were available, the recycling of white goods could yield considerable amounts of non-ferrous as well as ferrous metals. For example, an average refrigerator contains 117 kg of steel as well as 5.4 kg of copper and brass and 4 kg of aluminum. But Beak (1977) found little automation in Alberta scrap yards. Recyclable materials were stripped and sorted by hand, which raised costs and reduced returns to non-profitable levels.

The quantity of metal beverage container scrap available in Alberta was calculated based on returns to the bottle depots adjusted for a rate of return of 65 percent (Beak 1977). Beak estimated that in 1977 about 51 million non-refillable beverage containers were used and about 2.33 million were recovered. About 1,500 tonnes of steel were recovered. According to Beak (1977), no attempts were made to recover aluminum or tin from these containers, but the situation has changed. Information provided by Taylor (n.d.), shows that between August 1 of 1983 and July 31 of 1984, Contain-A-Way, the Alberta company that handles all of the non-refillable containers, received 57 million bimetal cans and 10 million aluminum cans, which were subsequently processed to recover the aluminum and steel. The portion of beverages sold in aluminum cans is rapidly increasing. These containers are sold to scrap dealers and, through them, to steel and aluminum companies. The scrap value of these containers was $105,400 and $163,000 respectively in 1984. The ferrous scrap is processed in Calgary, while the aluminum scrap is exported or sold to Canadian users outside of Alberta.

Alberta's municipal waste stream could contain about 108,000 tonnes per year of metallic scrap (all metals), but recent information shows that none of this was being recovered (Table 1). The quantity of metals being landfilled was such that Beak (1977) suggested that it would be economically feasible to operate a detinning plant in either Calgary or Edmonton.

At about the same time, the City of Edmonton (1979) conducted a simple study to determine the feasibility of recovering ferrous metals from municipal waste at transfer stations. At these stations, waste is shredded and compacted to reduce costs of transportation to the landfill and to reduce space requirements at the landfill.

Metals were determined to compose 4.9 percent of the waste and ferrous metals were 88 percent of the metal fraction. For this reason and because of the ease of separation, the test concentrated on ferrous metals. The shredded municipal waste was passed on a conveyor under an electromagnetic drum to remove the ferrous metals. The material was then air-separated in an attempt to remove the trapped non-metals. This is a simple form of the process used in many resource recovery facilities, although in some the metal fraction is lightly flamed to incinerate plastic and paper trapped in the shredded metals. The collected metallic fraction was then sent to several companies to determine market interest.

Ferrous metals recovered from municipal waste streams consist primarily of food and beverage containers. According to the report (Edmonton 1979), food containers are 92.8 percent steel, 1.7 percent tin, 2.8 percent lead (used as solder), and 2.7 percent organic coatings. Ferrous beverage containers are 87.8 percent steel, 10 percent aluminum, 0.1 percent chromium and 2.1 percent organic coatings. Because of the high levels of metals other than steel, steel manufacturers use "tin" cans as a small and carefully controlled fraction of their scrap feedstock. Other potential outlets for tin cans are detinning facilities where tin and steel are separated and recovered or in copper mining as a means of extracting copper from very low grade ore.

At detinning facilities, the containers are treated with a hot caustic solution to strip the tin from the container. The tin is then removed from the caustic solution by electrolysis. High-grade tin is recovered and the steel is sold for reprocessing. For best results, the detinning process requires ready contact between the caustic solution and all parts of the can. The balling and folding that occurred in the shredding of the waste in Edmonton's test meant that the waste was unsuitable for detinning. The only operating detinning plant in Canada is in Hamilton, Ontario. The majority of their raw material is scrap from the container manufacturing industry, although some clean containers are available through curbside collection systems now operating in Ontario. The supply of containers through the curbside collection program is encouraged by the industry through publicity, a set price floor for scrap, and a transportation subsidy (Parker 1984).

The use of tin cans in copper mining is an interesting application. If copper ore is treated with sulphuric acid, copper is extracted from the ore as copper sulphate. If the copper sulphate solution is brought into contact with ferrous scrap, then ferrous sulphate is formed in preference to copper sulphate. The copper can then be recovered. Ferrous scrap from municipal solid waste as well as scrap from industry can be used for this process. Since the process demands a high surface-to-volume ratio, thin, flat surfaces such as containers are ideal. In addition, the scrap must be free from paper and plastic coatings. In Edmonton's test project, the shredding and air-separation processes used resulted in a material of little value for the copper mining process and transportation costs precluded economic hauling (Edmonton 1979).

The final potential market investigated for the ferrous scrap recovered from Edmonton's municipal waste stream was the metal scrap dealers and steel mills. While some metal dealers expressed interest in the product, they generally considered it too contaminated by metallurgical and organic compounds to be usable (Edmonton 1979). The steel industry said they were adequately supplied with cleaner scrap. The prices offered by any of the potential markets did not cover the cost of separating the metal scrap from the municipal waste stream.

Non-Ferrous Metals

The amount of non-ferrous metals available in Alberta was estimated in 1977 at 63,000 tonnes per year (Table 1). According to Beak (1977), the non-ferrous scrap available would consist of about 29 percent aluminum, 31 percent copper, 18 percent lead, and 22 percent zinc, nickel, and stainless steel combined. Accurate figures on the use of non-ferrous metals were not available, but Beak reported that about 400 tonnes per year of aluminum

were being processed in Alberta in 1977 in addition to some processing of lead. With increasing use of aluminum cans in Alberta, aluminum recycling may gain greater importance. In the United States, recycling of aluminum is a very large industry. According to Hertzberg (1984), recycling of aluminum beverage containers has grown from 23,900 tonnes in 1972 to 450,000 tonnes in 1984 in that country. In 1981, about 30 percent of world aluminum production came from scrap, split about equally between industrial and post-consumer scrap. World trade in 1980 in scrap aluminum totalled about $600 million (U.S.) (Chandler 1984). Chandler reports that recycling of aluminum requires about one twentieth of the electricity and results in a 96 percent reduction in air emissions compared with extracting the equivalent amount of aluminum from ores.

3. PROBLEMS AND OPPORTUNITIES

Metals recycling in Alberta is hindered by a lack of information. It is difficult to determine the amount of industrial scrap available and even more difficult to determine the quantity of post-consumer or obsolete scrap. Calculations are hampered by a lack of comprehensive production data and good estimates of product life expectancies, and reuse or repair data. However, the rough estimates available indicate that, while considerable amounts of industrial scrap are being recovered, substantial volumes of metallic scrap end up in landfills. The major question is whether this wasted scrap is available in the quantities, quality, and locations to justify expansion of the metal recycling industry in Alberta. For example, would a detinning plant be economically viable in Alberta if containers were to be made available through curbside collection or post-collection separation? The very likely possibility that plastic will increasingly be used to replace metal in container fabrication, thus making any plans for a detinning facility impractical, must also be considered.

Beak (1977) reported that scrap yards in Alberta were generally low-capital, low-technology, labor-intensive operations. These operations cannot take advantage of potential opportunities for expansion of recycling. To be competitive they need technologies to efficiently process, separate, and extract various component metals. Development of operations capable of handling and processing a wide range of scrap materials to a quality suitable for recycling at low cost is a form of high technology that has not been adopted in Alberta. Adoption of new technology is required if appliance materials recycling is to compete with landfilling as an alternative disposal method. Yet incorporation of new technology would mean substantial investment by an industry that is already undercapitalized. According to Beak (1977), one factor inhibiting the adoption of new technology was the federal taxation policy, which was different for scrap and virgin materials. Scrap dealers were considered to be retail trade industries and therefore were not permitted a depletion allowance. The extraction industry, however, received this allowance, thereby giving them an unfair edge in the opinion of the scrap dealers.

One change in technology that has proven to be very beneficial to the metal scrap industry is the increasing use of electric furnaces by the steel industry. These furnaces permit fast, efficient processing of small batches of raw materials and are able to utilize 100 percent ferrous scrap. These characteristics allow the furnaces to be established as "mini mills." This has resulted in a reduction in the number of large integrated steel mills and their replacement with a greater number of smaller mills located closer to the market or to the

raw materials. The challenge to the scrap dealers now seems to be to supply these mills with the desired quality of scrap.

Dealers state that the Prairie region is scrap-deficient. Perhaps the difficulty rests with the scattered nature of scrap sources, which is in turn a reflection of dispersed population and the small-scale operations of the industrial sources of scrap. The available scrap may be dispersed or located a considerable distance from the few major users. It may be that the major sources of auto and farm scrap have already been tapped through various clean-up programs and new sources, such as recycling of appliances, need to be examined further. Can the scrap transportation system be improved, co-ordinated, or assisted in order to bring new supplies of scrap within economic reach of the markets? In the absence of a good information base, it is difficult to identify the potential for increased recycling and those directions that are potentially most rewarding for future initiatives.

Improvement in public education about metal recycling was identified by both Lazareck (n.d.) and Backman (n.d.) as having potential to increase material recovery. This is particularly important if the recovery of small amounts of scrap and appliances is to be improved. Special metal recovery areas could be set aside at landfills and public and municipal officials educated as to the use and role of these areas in metals recovery.

Metal recovery and reuse is occurring and, in some sectors, notably auto hulks, a significant proportion of the available scrap is being recovered. Other opportunities in metal recovery and reuse exist. However, because of a lack of good, up-to-date information, it is difficult to accurately assess which opportunities offer the most potential. Better data are required, an area where government could play a useful role.

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RUBBER

1. THE RESOURCE

Rubber is a name given to a group of organic substances having as a common characteristic the ability to return to the original form after being placed under stress. Rubber may either be obtained from natural sources or manufactured from organic chemicals (hydrocarbons). Natural rubber, which was so important 50 years ago, has been replaced or supplemented by synthetic rubbers in many applications.

The general-purpose synthetic rubber that has replaced natural rubber is a styrene-butadiene rubber (SBR), a polymer of styrene and butadiene. SBR rubber is used primarily in manufacturing tire carcasses. Different types of rubbers and additives may be used for sidewall, carcass, tread, and inner-wall components of a tire in order to satisfy the desired characteristics of each component. Other important synthetic rubber polymers are cis-polybutadiene (BR) and acrylonitrile-butadiene (nitrile) co-polymer. These rubbers are frequently used in tire tread and to add strength and flexibility to plastics, as well as in resilient foams and outdoor footwear. Nitrile rubber also is used for seals, gaskets, and other items subjected to contact with hot oils, and is added to fabrics to increase waterproofing.

Butyl rubber (a polymer of isobutylene) and trans-polyisoprene are also produced. Butyl rubbers have the special property of low permeability to gases, and are extensively used in inner tubes and in the inner linings of tubeless tires. They are also used for applications such as automobile window stripping.

In the manufacturing of rubber products, the primary rubber polymer is combined with many other materials to give a product its final characteristics. For instance, the final rubber used in a tire contains about 40 to 50 percent by weight of carbon black for strengthening, and may also contain: zinc oxide as a curing agent and pigment, antimony and arsenic compounds as mold and algae inhibitors, cobalt and boron compounds for adhesion enhancement, and sulphur from the vulcanizing process. Other chemicals that might be added include barium, lead, copper, cadmium, calcium, sodium, and potassium (Harrison and Grostern 1983).

Vulcanization, the chemical reaction of rubber with sulphur, causes cross-linkages to form between the polymer chains in an irreversible reaction. Vulcanization and final product molding usually occur at the same time under high temperatures. Vulcanization gives the product high tensile strength, elasticity, and improved resistance to high temperatures.

Table 2 provides data on the use of rubber compounds in Canada. These compounds are used to produce many products including: tires, tubes, hoses, belting, heels and soles for footwear, rubber footwear, cushions, mattresses, carpet underlay, pillows, and a wide range of molded products. Production of these items provided Canadian manufacturers with sales at the wholesale level of $948 million in 1975 (Environment Canada 1977).

Table 2. Consumption of Rubber Polymers in Rubber Fabrication, 1975

	Tonnes	Percent
Natural	5,200	2.0
Other Natural Rubber	68,300	25.8
SBR Latex	32,600	12.3
Other SBR	89,800	34.0
Nitriles	2,300	0.9
Polychloroprene	5,600	2.1
Butyl Rubber	8,500	3.2
Polybutadiene	26,600	10.1
Polysoprene	4,800	1.8
Ethylene-propylene Rubber	4,600	1.7
Other Synthetics	3,700	1.4
Reclaimed Rubber	12,500	4.7
Total Rubber	264,500	100.1

Source: Environment Canada 1977

By far the largest proportion of rubber produced goes into tires – they have consumed up to 70 percent of all primary polymers produced in Canada. Table 3 shows that 172,300 tonnes of rubber were used in the production of tubes and tires in 1975. In that same year, 17 million passenger-car tires were consumed. In addition, approximately 3 million tires were used on trucks and buses. Industrial machinery tires and tractor tires also are major consumers of rubber. In 1975, over 170,000 industrial tires were produced in Canada, while imports reached 195,000 units. Almost 500,000 tractor tires were manufactured in Canada and 318,000 were imported (Environment Canada 1977).

Other major uses include the fabrication of cushions, carpet, and underlay. While rubber is still important in the manufacturing of foam cushions, it is being replaced by polyurethane foam. The quantity of rubber used in carpets and underlay was estimated in 1975 at 12,200 tonnes of SBR in latex foam for carpet backing and about 11,500 tonnes of rubber for underlay. An additional 550 to 680 tonnes of sponge rubber were imported for use in carpet underlay.

Table 3. Applications of Rubber in Canada, 1975

	Tonnes	Percent
Tires, Tubes	172,300	65.1
Wire and Cable Wrappings	2,300	0.9
Footwear	6,900	2.6
Foamed Rubber	12,200	4.6
Rug Underlay	11,500	4.3
Other Rubber Products	59,500	22.5
Total Rubber Consumption	264,700	100.0

Source: Environment Canada 1977

2. RECYCLING

Recycling Pathways

The opportunities for recycling rubber follow a hierarchy: recycling of rubber into the same products (primary recycling), recycling into other rubber products with less strict specifications (secondary recycling), recovery of materials or chemicals from the rubber (chemical recovery), and recovery of energy.

Primary Recycling

In the manufacturing of rubber products, rubber polymers are blended with other materials and vulcanized to give the final rubber its desired characteristics. Crude rubber wastes that have not been vulcanized can be immediately blended back into the fabrication process and reused. A report by Environment Canada (Environment Canada 1977) suggests that, nationally, losses of primary polymer to the general waste stream are likely to be substantial, but firm information on reuse versus waste generation is not available because of the policy of confidentiality established by the industry. Since the rubber manufacturing and fabrication industries are concentrated in Ontario and Quebec, the amount of waste generated in the Prairie provinces from rubber fabrication is small. It was estimated to be 45 tonnes in 1975, increasing to 135 tonnes by 1990.

Secondary Recycling

Estimates of the amount of scrap rubber produced in the manufacturing of goods are shown in Table 4.

Rubber can be reclaimed from the scrap, through chemical digestion or mechanical means, which separate the rubber compounds from the non-rubber materials. Vulcanization of rubber changes its basic properties so that the rubber can no longer be reused in the same

Table 4. Waste and Scrap Rubber Generated in Canada During the Production of Goods, by Polymer Type

	Tonnes			% of Polymer Consumed*
SBR Latex	500	–	773	2.4
Other	318	–	454	0.5
Polybutadiene	114	–	136	0.5
Butyl Rubber	34	–	45	0.5
Other Synthetics	68	–	114	3.1
Natural Rubber	227	–	364	0.5
Reclaimed Rubber	34	–	45	0.4
Total Waste and Scrap	1,295	–	1,931	

Source: Environment Canada 1977

*Based on the high estimates of scrap and the consumption of rubber polymers given in Table 2.

fabrication process. In theory, vulcanized rubber can be reworked to make it suitable for use as a raw material, but in practice vulcanized rubber waste is either discarded or used in other products in its vulcanized state. Waste is particularly apparent where the product requires shaping and sizing after fabrication, for example, in the carpet, footwear, and apparel industries.

Some reclaimed rubber can be used in manufacturing depending on the rubber specifications for raw materials used in the process. It can also be used in surfacing materials such as running track, synthetic turf, arena floors, rubber mats, and in lower quality products such as footwear, adhesives, and flooring. Reclaimed rubber is also used to retread tires. However, in most of these latter uses, the use of reclaimed rubber is declining since the ease of producing synthetic rubber has reduced the value of reclaimed rubber. In addition, tighter specifications for tires and the increased use of radial tires have substantially reduced tire retreading. Use of reclaimed rubber is most profitable where it can replace costly natural rubber. Despite these constraints, Canada still imports a large quantity of reclaimed rubber. In 1975, 5,590 tonnes valued at $370 per tonne, or $2,070,000, were imported (Wardrop 1977).

Rubber, especially from tires, also is used in limited quantities to produce items such as washers, shims, shoe soles, ribbons for dock bumpers, and floor mats that are punched directly from split and cut tires. Attempts have been made to sell rubber crumb as a soil conditioner, but this has not been accepted in the market place. Rubber crumb can also be used in asphalt paving.

Chemical Recovery

Rubber may be subjected to pyrolysis, a process in which organic substances are heated under oxygen-starved conditions to extract oil, fuel gas, carbon black, or other materials (Dodds et al. 1983). However, the specifications for carbon black for use in new tire production are so rigid that it has proven very difficult to market carbon black recovered through pyrolysis of rubber at a competitive price.

Energy Recovery

An average scrap passenger tire may contain 27,100 kilojoules of energy per kilogram* (Wardrop 1977). Rubber may therefore be incinerated either for the purpose of utilizing the energy value or as a disposal method. For example, Canada Cement Lafarge Ltd. has tested fueling of its cement kilns with mixtures containing up to 30 percent granulated rubber (Nisbet 1984).

Materials Available

No recent work has been done nationally or provincially on the potential for recycling of rubber products. The information used here is drawn from studies done in the late 1970s. In the intervening period, the status of rubber recycling has probably changed due to improvements in recycling technology, changes in rubber product costs and the value of recovered materials, and, since tires consume the bulk of rubber materials, changes in automobile and truck tire sizes and specifications. More recent information is needed to identify the true potential for recycling rubber.

A comprehensive study by Wardrop (1977) investigated the potential for rubber recycling on the Prairies. According to information gathered at that time, about 55,000 tonnes of virgin rubber were used each year in the Prairie provinces. Estimates by Environment Canada (1977) indicate that the total amount of rubber discarded on the Prairies in 1975 was 44,000 to 48,000 tonnes in all products.

Wardrop (1977) estimated that rubber formed only about half a percent of the municipal waste stream. Therefore, segregation of rubber materials from the municipal waste stream was not expected to be economically feasible. Wardrop (1977) also did not consider it practical to recover non-tire rubber products although they total 30 percent of rubber production, because of their diffusion throughout the economy. In Wardrop's view, except for exceptional cases, recycling opportunities are concentrated in recycling of scrap tires. Based on vehicle registration information and assumptions about the average weight and life-span of the tires, Wardrop (1977) estimated that 27,000 tonnes of tires were scrapped on the Prairies in 1976. About 12,700 tonnes of these were discarded in Alberta. These figures include passenger vehicle tires, truck tires, and tractor tires. Because some of the discarded tires are already used in reclaim operations or in fabrication plants, not all discarded tires would be available for additional recycling uses. The present collection and

*A kJ/kg or kilojoule per kilogram is a measure of energy content. Approximately 4.2 joules of energy are required to raise the temperature of a gram of water by 1 Celsius degree.

disposal methods are not well developed and a large portion of the discarded tires would be difficult to recover, especially in rural areas. Wardrop concluded that less than half of this weight, or about 5,400 tonnes, could be classified recoverable in 1974. The bulk of this rubber was estimated to be located in Edmonton (3,200 tonnes) and Calgary (1,400 tonnes). The recoverable amount was projected to increase by 1988 to approximately 8,500 tonnes annually.

Recycling of tires may be attractive not only because tires are a substantial fraction of discarded rubber products, but also because they are readily available and difficult to dispose of. If tires are buried in landfills they have an annoying habit of rising to the top over time because they trap air and toxic gases or liquids, and since they are flexible, they act like balloons. Tires cannot be compacted and hence take up considerable space per unit of weight. They also are unsightly if stockpiled, may provide habitat for pests, and are a fire hazard. Some landfills in eastern Canada and in the United States either will not accept tires or levy a surcharge for their disposal. For this reason stockpiles of discarded tires exist. As an example, although it accepts them, the Calgary landfill segregates tires and buries them in a special section of the landfill.

Tires can be burned in municipal waste incinerators either whole or shredded. However, without special precautions or modifications to the incinerator, whole tires can form a glutinous mass that clogs grates and obstructs air flow. The steel belts also tend to block the feed mechanisms (Wardrop 1977). Because the heat of combustion and the air requirements are higher than for normal municipal waste, incineration of tires can create hot spots in the incinerator and damage the refractory lining, or cause incomplete combustion and resultant air pollution problems.

Tires have been used in breakwaters and artificial reefs and as highway crash barriers. But these uses require only a few of the tires discarded each year.

Tires may also be retreaded so that their useful life is extended. It was estimated that in 1975 about 15 percent of the replacement tire sales in Canada were retreaded tires (Wardrop 1977). Use of retreaded tires is much more common for trucks and buses. According to Wardrop (1977), retreaded tires were reported to be meeting 37 percent of the replacement truck tire demand in the United States. Because of the greater replacement costs of these larger tires, more care is given to retreading them while it is still possible to do so. Many passenger tires are too worn to be suitable for retreading. The increasing use of steel-belted radial tires is also causing difficulty for the retreading industry since the technology used for retreading bias-ply tires is not applicable to radial tires. However, a company in Ontario is now using European technology to remold worn radial tires. Because retreading of tires involves heating and molding, a different mold is required for each tire size. The recent increase in the variety of tire sizes available has also hurt the retread industry.

According to Wardrop (1977), tire rubber can be used as rubber crumb in asphalt paving. If rubber crumb could replace one percent of the asphalt applied each year, the demand for rubber would exceed the estimated supply. This is the only use his report considered to show immediate economic promise. Considerable experimentation occurred in the late 1970s on this use of discarded rubber, spurred by the rapidly rising costs of asphalt.

The experiments showed promising results using rubber crumb either for rubberized asphalt paving or for a seal coat on asphalt concrete (Wardrop 1977). Rubber crumb of about 0.6 mm size used in rubberized asphalt paving apparently resulted in longer pavement life, improved ride, less brittle pavement, better adhesion between asphalt and the aggregates, increased resilience at low temperatures, decreased flowing of asphalt at high temperatures, reduced skidding, and reduced tracking (Wardrop 1977).

The Alberta Department of Transportation has tested rubber crumb in three different types of application (G. Berdahl 1985: pers. comm.). Rubber crumb was tested in a seal coat application in an attempt to reduce pavement cracking caused by temperature fluctuations. However, the production and placement of the rubber-asphalt mix required special equipment and presented operating difficulties. This increased construction costs significantly, and the expected benefits were not achieved; therefore, the use of rubber in seal coat was considered uneconomic. Rubber crumb blended with asphalt was also used as an interlayer over a "soil cement" base course, in an attempt to reduce the pavement cracking caused by natural contraction of this material during curing. Results are still under evaluation. The third and most recent trial involved the use of coarse rubber granules mixed with asphalt as the pavement surface. The effectiveness of this process, which is reported to increase shedding of ice by increasing pavement flexibility, is still being evaluated.

Wardrop (1977) suggested that a sufficient supply of rubber crumb could be recovered using the present collection system in the major cities. In this system, tires are collected by private operators and sorted for resale, retread, or discard. Discarded tires are landfilled or stored. Tires could be transported from small towns on a back-haul basis to reduce costs. The tires could be shredded at one or more regional shredding facilities (shredding reduces bulk and hence transportation costs). The shredded tires would then be transported to a central processing facility serving the Prairie provinces or to provincial processing facilities. There the shredded tires would be frozen by spraying them with liquid nitrogen and, in this brittle state, pulverized in a hammermill. This cryogenic grinding process separates rubber from other materials such as fabric and steel fibers. These undesirable materials can then be removed by magnetic separation, screening, or air separation.

According to calculations in the report (Wardrop 1977), the benefits of this utilization of rubber would far outweigh the costs, since the initial capital investment in the rubber processing facility is small compared to the benefits. The report estimated that a 5.5 tonne per hour cryogenic rubber recovery plant would cost $2,145,000 (1978 dollars) and generate benefits of $118 million over a 10-year period.

3. PROBLEMS AND OPPORTUNITIES

Because substantial amounts of rubber are presently discarded as waste, it appears that there could be a number of opportunities available either to recycle this waste through reuse in other rubberized products or through recovery of energy.

The best opportunity for recovery of discarded rubber seems to be in the transportation sector in the form of tires. Other rubber discards are already used or are not available in segregated amounts sufficient to justify recovery. Once rubber wastes are mixed with

each other or with municipal waste, resource recovery seems to be limited to systems that could handle mixed refuse through pyrolysis or incineration and energy recovery.

Discarded tires are used in several forms: retreading, splitting and use of tire materials with little processing, grinding and treating to make other products, pyrolysis, or incineration.

Use of retreaded tires is hampered by the availability of low-priced new tires that are better accepted by consumers, the shift to longer life radial tires, the stringent specifications for tires, and the wide range of tire sizes. These constraints would have to be overcome before retreaded tires could gain a larger portion of the replacement market. The newly opened facility in Ontario for retreading radial tires may indicate future expansion of this market. Wardrop (1977) suggested that adoption of standards for retreaded tires could improve their acceptability, but these tires would still have to compete with inexpensive new tires.

The use of tire material in other rubber products with or without processing appears to be limited mainly by the market demand for the types of products that can be produced, although technical problems in reclaiming rubber also need to be overcome. Some products are sensitive to the price of virgin rubber products or to similar products made from plastics. Reclaimed rubber is used to a limited extent in the manufacture of new tires. On average about 5 percent of the rubber polymers in new tires may be reclaimed rubber; lower priced tires generally contain more. But reclaimed rubber is of demonstrably lower quality than virgin rubber. There is deterioration in strength, uniformity of polymer, and heat and abrasion resistance (Wardrop 1977). Products made from reclaimed rubber or discarded tires include battery cases and covers, tire repair material, inner tubes, steering wheels, auto mats, belting, hoses, and packing. However, many of these products do not compete well against colored plastic products. Low disposal costs and the fluctuating price of virgin synthetic rubber and plastics also affect the viability of production firms specializing in reclaimed rubber. Most such operations are small and local; therefore availability of supply and transportation costs may not be a major concern. There are no facilities in Alberta using discarded tires as the raw material for other products. However, some rubber is sent from Alberta to a firm in British Columbia, which uses it to manufacture rubber flooring for stables, barns, and arenas.

Pyrolysis and incineration for energy recovery may provide a future use for the large amount of rubber discarded in tires, but no facilities yet exist in Canada. The success of such facilities is affected by the value of the materials or energy that might be recovered and the value of virgin materials or substitute fuels the rubber would be displacing. Quality of products is a significant concern affecting the economic operation of pyrolysis facilities in the United States.

Stability of supply is also an important factor in attempts to use rubber as a fuel in cement kilns. Experimental burns in Montreal indicated that shredded rubber could replace up to 30 percent of the present gas or coal used in a cement kiln with no detrimental effects on product quality or air emissions. Although there were some initial problems with inconsistent feeding of the rubber into the kiln and blocking of the screw conveyors with wire and fiber, these difficulties were overcome and shredded tires proved to be a suitable fuel.

However, at the 30 percent level of fuel replacement, the kiln would require about 1.5 million tires per year (Nisbet 1984). This amount of material (which represents almost total recovery of the tires discarded annually in the area) would have to be supplied to the kiln shredded to pieces about 16 mm in diameter. Maintaining this level of supply is unlikely. Collection, transportation, and shredding capacity would all need to be developed.

Development of this infrastructure might be encouraged by reducing disposal costs to encourage collection at disposal sites, a deposit/refund system, establishment of municipal collection depots, or tighter disposal regulations. In addition, supply may decline with the decrease in average car size and hence tire weight, longer tire life, replacement of spare tires by temporary tires, and greater use of all-weather tires. Harrison and Grostern (1983) suggest that use of tires as fuel in cement kilns should be considered only as a temporary measure. Once the infrastructure is developed to collect and handle the large volume of tires, other processes that could make better use of the resource might be encouraged and tires would be diverted from use as fuel.

What are the opportunities for recycling the discarded rubber? Since the available information indicates that approximately 70 percent of all primary rubber polymers produced in Canada are used in the production of tires, recovery of discarded tires and the reuse of the rubber or recovery of the energy content would seem to provide an excellent starting point for increased rubber recycling.

At present some tires are being retreaded, rubber is being reclaimed for other uses, and rubber crumb is being produced for use in other products. But these uses consume only a small fraction of the rubber discarded annually. Is recovery of the remainder viable? Use in cement kilns or in properly designed energy-from-waste plants is feasible. Is this a suitable alternative for Alberta? Or is incineration an essentially temporary use that would establish the collection network and develop rubber supplies, which then would be available for higher and better uses? Would any cement manufacturer or incinerator for energy recovery be willing to act in such a transitory capacity? These are some of the questions that must be answered if the province is to take advantage of opportunities for increased recovery and recycling of rubber.

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GLASS

1. THE RESOURCE

Like other products, "glass" is in fact a wide range of materials that have different colors and chemical compositions depending on desired uses and characteristics. Because glass container production in Canada is dominated by two companies, detailed information on inputs and outputs is kept confidential. However, information is available from Statistics Canada on the amount of raw materials used in the production of glass and glass products and a conversion of these data to an estimated glass output is possible. Pilsworth (1984) estimated Canadian glass production at 1,112,000 tonnes in 1982. If Canadian operations reflect the United States experience, it is likely that about 70 percent of this glass is used in production of various types of containers. Although a breakdown of production output is not available, data shown in Table 5 indicate that, based on product value, the majority of

Table 5. Consumption of Glass Containers by Canadian Industry

	1981	1982
	(thousands of dollars)	
Fruit and Vegetable Canners and Preservers	52,384	56,267
Miscellaneous Food Processors	37,493	35,342
Soft Drink Manufacturers	42,221	45,444
Distillers	79,131	86,247
Breweries	57,009	62,846
Wineries	32,304	35,394
Other Food and Beverage Industries	21,768	25,411
Food and Beverage Sub-total	322,310	346,951
Chemical/Chemical Products Industries Sub-total	36,983	38,953
Other Industries Sub-total	29	44
Total All Manufacturing Industries	359,322	385,948

Source: Pilsworth 1984:60

containers produced are soft drink, liquor, beer, and wine bottles. Data from the two Canadian glass container manufacturers show production to be 64 percent flint glass (colorless), 24 percent green glass, and 12 percent amber glass.

The most common form of glass, the type used in containers, consists of variations on a silica-lime-soda mixture. A typical recipe is shown in Table 6.

Table 6. Container Glass Recipe for Soda-Lime Flint Glass

	Percent
Silica Sand	58.8
Soda Ash (Synthetic)	15.1
Limestone	18.1
Nepheline Syenite	4.4
Other	3.6
	100

Source: Pilsworth 1984

The common source of silica is a special sand derived from quartz-sandstone and usually consisting of over 99 percent silicon dioxide. Purity requirements are strict and the sand is sorted to provide grains of uniform size. This is important because uniformity of size increases the predictability of melting in the heating process. The cost of the sand depends primarily on the location of the source and transportation costs.

Lime is normally provided as calcium carbonate from limestone or dolomite, while soda is provided as sodium carbonate manufactured from a chemical reaction of ammonia, salt, and carbon dioxide. The cost of soda ash has increased dramatically in the last few years and is probably the major factor contributing to higher glass prices (Pilsworth 1984). Sodium carbonate decomposes to sodium oxide in the manufacturing process, giving off carbon dioxide, which helps to stir the batch. Calcium carbonate acts similarly to soda, but also helps to make the glass inert to water. The three materials, silica, soda, and lime, are used to produce container glass. Variations in the proportions of these materials affect the glass characteristics. Other chemicals are added to make specialized glass: boron oxide, zinc oxide, and litharge or red lead. Coloring is the result of adding oxides of copper, chromium, cobalt, iron, or nickel. The materials must be of high and consistent quality. The standards for different types of glass can be very demanding. For example, domestic glassware may contain 0.05 percent iron oxide, while in higher grade materials this may be reduced to as little as 0.001 percent.

An important ingredient in the manufacture of glass is "cullet" or broken glass. Cullet is almost always used in the production of glass, usually as a small proportion of the batch, although it could be used in amounts as high as 100 percent. The use of cullet is important because glass becomes fluid at a lower temperature than its constituent raw materials. The

cullet acts as a solvent in the glass production process and speeds up the intersolution of the other materials. Cullet from any source may be used, but to ensure high quality in the final product it should be of the same type as the glass being manufactured.

2. RECYCLING

Recycling Pathways

Glass can be recycled along a variety of pathways. For example, glass can be recycled through reuse of products such as containers, or by using cullet as a replacement for raw materials in the manufacture of new containers. A secondary route is the use of cullet in other glass products such as glass beads or fiberglass or as a substitute for materials in products such as terrazzo tile or brick.

The simplest form of recycling is reuse of a product, such as the reuse of returnable soft drink bottles and beer bottles. After return to the bottle depot, the brewer, or an Alberta Brewers' Agent depot, the bottles are returned to the distributor, washed, and refilled. This is a very efficient use of glass containers and works well because the beverages are bottled at a local or regional level. Hence, collection and reuse of these bottles is not blocked by high transportation costs. However, the consumer has an important role to play in accepting and using refillable bottles in preference to non-refillables. Other containers could be reused or used for other purposes and probably are within many homes, but there is no "official" reuse of containers other than refillable beverage containers. According to Cavanagh (1985), the refillable glass market in the United States tends to lose about 2.5 percentage points to the non-refillable market each year. This trend seems to reflect consumer preferences, though the reason for the preference is unknown. Is it possible to maintain or expand the use of refillable containers?

Use of cullet in glass production offers a number of benefits. Through speeding the solution process and allowing it to occur at lower temperatures, energy is saved. Although the raw materials used in glass usually are common and easily obtained, their cost has increased dramatically in the last few years. The availability of cullet at a lower price than the raw materials results in reduced glass production costs. Recycling of glass also saves on disposal costs, increases the life of landfill sites by reducing the waste volume, and reduces littering.

Attempts have been made to use pulverized glass rather than sand in concrete, asphalt, and brick (Alberta Environment 1979). In these applications mixed glass can be used. The glass apparently gives excellent qualities to these materials because it is strong and has better heat transfer properties than sand. However, these advantages are not sufficient to compensate for the additional cost of pulverized glass compared with sand. Cullet has also been used in pavement sealant, glass wool, wall panels, foamed glass, and terrazzo tile (Pilsworth 1984). Use of cullet in applications such as these may provide an important future market for contaminated cullet or cullet of mixed colors.

Another possible application is the use of cullet in glass polymer composite (GPC) sewer pipe. This pipe can be made from 87 percent waste glass by weight, 10 percent

styrene, and 2 percent polyester resins, with the addition of bonding agents, initiator, and an internal release agent. The advantage of the process is that the glass fraction may contain up to 5 percent contaminants in the form of ceramics, metal, and stones (Pilsworth 1984). The use of this pipe would depend on its cost and qualities in comparison with alternative products.

Materials Available

About 1,112,000 tonnes of glass were produced in Canada in 1982. About 179,000 tonnes of cullet, or 18 percent of the glass produced, were used in this production. Cullet use increased sharply from 65,000 tonnes in 1978 to 179,000 tonnes in 1982 (Pilsworth 1984), mainly in response to rising costs for energy and raw materials, and the increased availability of cullet collected through resource recovery programs. However, about 50 percent of the cullet used in Canada is imported from the United States (Marbek and Econome 1985).

According to Free (n.d.), the estimated total amount of municipal solid waste generated in Alberta is 1.8 million tonnes annually. Based on an estimated 5.19 percent of the municipal waste being glass, the maximum glass available in the waste stream is approximately 93,400 tonnes. These numbers provide an indication of the potential resource, but it must be stressed that, like all calculations related to waste generation and composition, they should be considered as ball-park numbers due to variations in local generation rates, composition, and methods of measurement. There is a lack of a good data base on various aspects of glass recycling including glass production data, the products manufactured, import and export sales, the extent of utilization of waste glass, and the amount of glass discarded.

Pilsworth's report (1984) also shows the glass fraction of the waste stream according to glass type (Table 7). This information reflects the operation of the Alberta bottle depot

Table 7. Percentage Composition of Glass in Alberta's Municipal Waste

	Percent in Municipal Waste	Percent of Glass Waste
Total	5.19	100
Beer	0.13	2.5
Reusable Soft Drink	0.08	1.5
Non-Reusable Soft Drink	0.22	4.2
Liquor and Wine	0.72	13.9
Food Containers	2.94	56.7
Other Containers	0.30	5.8
Flat and Cullet	0.80	15.4

Source: Pilsworth 1984

system. Because of the success of the depots, the bulk of the glass remaining in Alberta's waste is food containers. Beverage containers compose 22 percent of the glass waste in Alberta, while food containers contribute more than 56 percent. As a national average, glass is 6.61 percent of the waste stream and beverage containers represent 45 percent of the glass waste (Bird and Hale Ltd. et al. 1979). Alberta's Beverage Container Act and associated bottle depots thus appear to have significantly reduced the volume of beverage containers in the waste stream. According to Rogers, about 7,400 tonnes of refillable containers and 29,000 tonnes of glass from non-refillable containers were recovered in 1982 through the Alberta bottle depot system (T. Rogers 1985: pers. comm.). The bottle depot system has thus reduced Alberta's waste glass load by approximately 38 percent. But are there ways in which this could be improved? How could food containers be best collected for recycling?

Present Use

There are two plants operating in Alberta which manufacture glass products and which purchase cullet made available through the Alberta beverage container depots or from industrial sources. One company, Domglas in Redcliff, which manufactures glass containers, uses cullet as a substantial portion of the raw material in its operations. Cullet has the advantage of being abundant locally because of Alberta's beverage container legislation. It is available at less cost than the raw materials since transportation costs are about 50 percent of raw materials costs. Both post-consumer cullet and cullet generated within the plant from the container-forming process are used. In 1982, Domglas used about 60 percent or about 17,400 tonnes of cullet from non-refillable bottles recovered through the bottle depots in Alberta (T. Rogers 1985: pers. comm.). A much smaller amount of cullet is obtained directly from the Alberta Brewers' Agents and soft drink bottlers.

Cullet received from outside sources may be contaminated with residues, metal closures, foil labels, and inorganic compounds, and must be sorted, processed, and cleaned. Cullet is crushed to an appropriate size and screened to remove oversized pieces, and ferrous metals are removed magnetically. Labels and aluminum closures pose some difficulty, but can be handled in the manufacturing process. Only container glass is accepted at the Domglas plant in Alberta because this gives a high probability of similar composition in the glass. Other glass such as window and auto glass is not accepted because it is not available in quantities sufficient to justify the process changes required to deal with it. While Domglas is prepared to purchase any cullet delivered to its gate, the cullet must meet specifications regarding color separation and cleanliness (Gibbons n.d.). The prices offered in 1984 ranged from $26 to $54 per ton depending on the amount and means of delivery. Because of the high costs for transporting raw materials, Domglas also is able to offer a transportation subsidy to assist in the delivery of cullet. This subsidy depends on the transportation distance, but is approximately $1 per ton for each 100 km travelled.

The other company accepting clear cullet in Alberta is Canasphere Industries, which has plants in Calgary and in Moose Jaw, Saskatchewan. These plants do not produce glass and therefore rely on the availability of foreign (post-consumer) cullet. The plant in Calgary uses mainly liquor bottle cullet obtained through the bottle depot system, but also gets a small amount of cullet from industrial sources. The plant in Moose Jaw gets about 80 percent of its cullet from the plate glass and window glass manufacturing sector, trucking this cullet from Winnipeg. Some bottle glass, originating in all three Prairie provinces, is also

used (J.R. Steinmann: 1985 pers. comm.). Rogers estimates that Canasphere used about 11,600 tonnes of Alberta cullet in 1982 (T. Rogers 1985: pers. comm.).

Canasphere Industries produces glass beads. Cullet is pulverized and sieved before being fed into gas furnaces. As the pulverized cullet rises in the air stream in the furnace, it melts into spheres. The spheres are pulled off from the top of the furnace and graded by size. They are then used in reflective highway paint and in applications such as sandblasting, deburring, peening, and as the support medium for hospital beds for burn victims (Steinmann n.d.). The glass beads have been sold throughout Canada and much of the United States as well as overseas.

3. PROBLEMS AND OPPORTUNITIES

As with most other recycled materials, clean cullet of uniform color and known composition generates the greatest value and is most readily reusable. A certain degree of impurity is acceptable in the glass manufacturing process because impurities may be incorporated in the glass or burned off. There are limits to the contamination that can be accepted, since certain types of glass are incompatible and very small amounts of some contaminants can alter the properties of the glass.

Color separation is probably the most important limiting factor. Most cullet received through glass recovery systems is either mixed, green, or plate glass, all of which can be used to manufacture green glass. The tolerances of other glass for mixed cullet are not as high. Flint glass, for example, may contain a maximum of 5 percent amber cullet or 1 percent green cullet. Amber glass may contain up to 10 percent flint or green cullet, and green glass may contain up to 15 percent flint cullet or 35 percent amber cullet. According to information supplied by the two Canadian glass container manufacturers (Pilsworth 1984), the production output of containers by color is: flint 64 percent, green 24 percent, and amber 12 percent. Hence, provision of color-sorted cullet is important if its use is to expand. If glass waste could be color-sorted, theoretically up to 100 percent cullet could be used and the demand would increase substantially.

In Alberta, recycling has been limited to cullet collected through the bottle depot system, cullet generated by bottlers, and cullet resulting from manufacturing at the glass plant. The sources all supply reasonably clean, color-sorted cullet. While other post-consumer glass may be returned to the Edmonton and Calgary warehouses of Contain-A-Way, the Alberta company responsible for handling non-refillable beverage containers, or to the glass producers, no systematic attempt has been made to encourage collection of glass food containers.

The challenge, if we accept it, is to collect clean and color-sorted containers from the approximately 93,400 tonnes of glass disposed of annually. Once glass has been mixed with general waste, it is difficult to segregate and nearly impossible to classify. Its usefulness is therefore limited. If all glass containers, including beverage containers, were removed from the municipal waste stream, the glass fraction would be reduced to about 0.80 percent of all waste. Are there specific areas of research that would assist in finding uses for contaminated glass or provide innovative techniques for processing and cleaning such glass?

If cullet could be supplied color-separated and contaminant-free, priced competitively with raw material, there appears to be room for a substantial increase in demand for cullet. But how can increased recovery be achieved? Several options exist: source separation programs, expansion of the bottle depot program, drop-off centers, or a deposit on containers other than beverage containers. Other alternatives include transportation assistance for collectors of recycled glass in communities distant from markets for the glass, and accelerated capital cost allowances (as are presently available for pollution control devices) for equipment used in glass recycling.

While programs to allow source separation and recovery of post-consumer glass are in place in a number of communities in other provinces, data, particularly on cost, are often not available. It is difficult to determine the most cost-effective approaches to glass recovery and those approaches suitable for use elsewhere. The lack of information makes planning for activities to improve recycling very difficult. Governments, either at the provincial or federal level, could do much to improve data collection and information dissemination as well as supporting technology development related to collection, processing, and handling of post-consumer glass; color sorting; and the use of contaminated glass (Pilsworth 1984).

A major question for Alberta is whether to maintain the beverage container collection system as it is, to expand it to accommodate other types of food containers, or to implement another program to collect glass containers.

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LUBRICATING OIL

1. THE RESOURCE

Lubricating oils have a wide range of uses related to their properties of reducing friction and wear between moving parts. They are used for lubrication of automobiles, tractors and trucks, stationary engines, compressors, turbines, pumps, gears, and chains, and in hydraulic systems. This range of uses requires a complementary range of properties in the lubricating oils. The properties are achieved through addition of a variety of chemicals for specific purposes. Chemicals are added to the base oil to inhibit rust, corrosion, oxidation, and the growth of micro-organisms, to mask odors, disperse contaminants, prevent congealing, maintain viscosity, and generally enhance the ability of the oil to perform specific tasks (Sykes 1978). Lubricating oils consist of approximately 10 to 12 percent by volume of these additives (Shimbashi 1980a).

The base oil for the vast majority of lubricating oils is refined from crude oil. But it takes a special crude oil to be suitable for use in lubricating oils and 16 to 30 tonnes of suitable crude oil may need to be refined to produce one tonne of lubricating oil (Sykes 1978). In 1976, Canada was a net importer of lubricating oils, with net imports being 22 percent of the total use. In addition, some domestically produced lubricating oils were refined from imported crudes (Sykes 1978).

The properties of oil change during use, as additives are modified by heat, friction, and contamination, and oil quality is degraded by oxidation and combustion. However, the base oil remains unchanged. Base oil can be cleansed of additives and impurities and returned to a state similar to, and some say better than, the virgin oil base. Additives can then be re-added to give the lubricating oil its desired properties.

2. RECYCLING

Recycling Pathways

Re-refining of lube oil is not new. Re-refining methods were developed as early as 1915 (Cameron n.d.). However, as the composition of lubricating oils became more complex in response to new uses and the more demanding specifications of modern engines, re-refining technology became more complex and more expensive. Increased re-refining costs meant that re-refined oils were less competitive with virgin lube oils. Production of re-refined oil in

the United States peaked in about 1960 with a production of 1.14 billion litres. It has now fallen to a level of about 190 million litres per year (Cameron n.d.). However, there is renewed interest in re-refining used oil and recently Canadian production capacity for re-refined oil has risen with the opening or expansion of facilities in Ontario, Alberta, and British Columbia.

Several processes have been developed to re-refine used oil. These processes include an acid-clay process, a distillation/clay process, a distillation/hydrofinishing process, the PROP/Shell process, and the Turbo Lubrefining process. This report does not discuss the details of these processes. Their intent is the same, to yield a base lube oil free of impurities and additives, and all of the processes can achieve this objective. Re-refined oil can replace virgin oil in the production of new lubricating oil, or can be blended with virgin oil in the final processing.

As well as being re-refined, used lube oil can be collected for uses such as road oiling or fuel. These uses are less desirable because they result in loss of the oil for other uses. As well, the used oil may be contaminated with lead and other materials such as calcium, barium, zinc, cadmium, aluminum, phosphorus, and carbon. Improper disposal or burning of used oil could pose environmental and health problems.

Moreover, collection of used oil for road oiling competes with its recovery for re-refining, even though road oiling is neither the most effective use of the oil nor an environmentally sound use. Heavy oil, which is not contaminated with impurities, additives, and detergents, would be more environmentally suitable as road oil and has fewer other potential uses than the light oil used as a base in lube oils. Nevertheless, road oiling with used lube oil is common because that oil is available at a lower cost than heavy oil.

Used lube oil is also used as a fuel. Its heating value depends on the amount of sediment and water present. According to Sykes (1978), the energy value is typically about 33,000 to 35,000 kJ/kg, which is greater than the energy value of most coals. While lube oils have a low sulphur content, there are concerns about the possible emission of metals and other trace elements, including lead, when the oil is burned without proper pollution control equipment. Users should also be aware of concerns about the fouling of boiler tubes, firebox and burner corrosion, and possible problems with handling and storage because of the presence of low-boiling contaminants such as gasoline or solvents (Sykes 1978).

Recycling of used oil offers many benefits: protection of the environment, betterment of our health and well-being, conservation of a non-renewable resource, reduction in the cost of waste management, and creation of a viable business and employment (Shimbashi 1980a). Shimbashi suggests that used lubricating oil be classified as a "hazardous waste" and legislation be put in place to direct it to recyclers instead of permitting its use as road oil or its disposal by normal landfilling. Is this a desirable and effective option for improving recycling of lube oil?

Materials Available

Substantial quantities of lubricating oil are used. According to Cameron (n.d.), 120 million litres of lubricating oil were sold in Alberta in 1983. How is the used lube oil disposed of?

While no recent comprehensive surveys have been done in Alberta, a survey by Synergy West Ltd. in 1974 provides useful information. Synergy West Ltd. (1974) interviewed oil users including petroleum companies, service stations, truckers, industrial users, government garages, transportation companies, waste oil collectors, and 'do-it-yourself" oil changers. The survey covered six municipalities (Grande Prairie, Edmonton, Red Deer, Calgary, Lethbridge, and Medicine Hat), but did not cover rural areas. The data show that in these municipalities lube oil sales totalled about 29.6 million litres in 1973. The volume of waste oil disposed of through known channels was 15.5 million litres or about 53 percent of the total oil sold in the area. This amount was defined as the maximum amount recoverable. The remainder was volatized, or otherwise dispersed to the environment, and was considered to be unrecoverable. Table 8 shows how the potentially recoverable oil was disposed of in 1973. In the major municipalities, about 51 percent (8 million litres) of the recoverable oil was actually recovered. The report noted that an area of concern was the disposal practices of small users. Much of their oil is either dumped or landfilled (Table 9).

A subsequent study of oil use and disposal practices in rural areas (Synergy West Ltd. 1975) estimated that 1973 sales of lubricating oils outside of the major municipalities totalled 59.7 million litres. About 31.5 million litres of this was termed recoverable based on a 53 percent recovery rate. Because of the more dispersed population, the inconvenient nature of drop-off points, and the difficulty inherent in running a rural pick-up service, little of the oil used in rural areas was returned for re-refining. While 51 percent of the oil used in the major municipalities was recovered and re-refined, the comparable figure for rural service facilities and agricultural oil combined was 2 percent. Table 8 also shows that outside the major municipalities the only used lube oil destined for re-refining was from rural service facilities. Farmers use the oil for dust and weed control on their farms or for oiling posts or as a bug deterrent for animals. A quarter of the used oil collected by rural service facilities was used for road oiling.

On a provincial basis, of the 89.3 million litres of lubricating oil sold in 1973, 47 million litres were deemed to be recoverable, but only 8.7 million litres or 19 percent were actually recovered for re-refining. These data indicate a substantial potential for improving the collection of waste oil. Synergy West recommended a province-wide waste oil collection and refining system.

A specific concern was the frequency of dumping of oil on the ground by agricultural users and road oiling in rural areas. Wherever convenient alternatives were not available, these disposal methods were in common use.

Present Use

Building on a base of these and other studies (Hougan 1979; Shimbashi 1980b; McLaren and Reeve 1982), Alberta Environment now has specific programs for encouraging collection of waste oil. In rural areas, funding is provided for purchasing and installing collection tanks at landfill sites, county garages, and service stations. When sufficient oil has been collected, it is picked up by a private-sector contractor or re-refiner. In 1984, the Department established the Oil Drop Program to improve recovery of waste oil from the "do-it-yourself" oil changer in urban municipalities. This program involves co-operation of dealers and service station operators throughout the province in establishing drop-off points. Approximately 350 service stations are now participating in this program.

Table 8. Final Disposition of Waste Oils in Alberta, 1973

Means of Disposal[1]	Percent of Total Volume Recoverable		
	Major Municipalities	Rural Service Facilities	Agricultural Oil
Re-refined	50.8	10	–
Landfill Sites	35.6	26	6
Road Oiling	8.4	25	–
Dumped at Source	4.8	8	43
Farm Use	0.4	9	44
Burned	0.1	2	4
Delivered to Service Station	–	–	1
Contract Pick-up[2]	–	17	–
Other	–	3	2

Source: Synergy West 1974 and 1975

[1] Slightly different classifications were used in the two reports. There may be some overlap between disposal methods.

[2] Usually deposited at landfill.

Table 9. Waste Oil Disposal Practices of "Do-It-Yourself" Oil Changers in Urban Areas

	Percent
Dumped on ground	22
Transferred to containers; placed in garbage	48
Taken to shop or other waste oil depot	18
Dumped down storm sewer	2
Other	11

Source: Cameron n.d.

Local efforts are also being made to recover waste oil. For example, the County of Flagstaff Solid Waste Management Authority has placed a 32,000-litre collection tank at the regional landfill site and has distributed about five hundred 45-gallon barrels to service stations and garages in the area. The waste oil collected in these barrels is picked up once per month and sold to a refiner. The Waste Management Authority estimated that it collected about 40 to 50 percent of the waste oil available in the area and, in the first 14 months of the program (up to December 31, 1983), collected 50,000 litres of oil that were sold for 5.7 cents per litre (Likness n.d.). In the first six months of 1985, the level of collection increased to 36,000 litres, which sold for 10.2 cents per litre (R. Judd 1985: pers. comm.).

3. PROBLEMS AND OPPORTUNITIES

According to estimates by Cameron (n.d.), of the 120 million litres of lubricating oil sold in Alberta in 1983, only about 23 million litres were recovered. This amount (23 million litres) is about 36 percent of the potentially recoverable used lube oil that was available in the province that year. This is a substantial improvement on the recovery rates of 1973 (from 19 percent in 1973 to 36 percent in 1983). However, potential for improvement exists. How can recovery of oil from the rural market and the "do-it-yourself" oil change market be improved? Cameron (n.d.) recommends that the government support development of recycling industries and greater public education to encourage used oil collection. A more extensive and regular pick-up service in rural areas may also help. If this is the case, whose responsibility is it to develop, promote, and pay for this improved pick-up service?

If improved pick-up in both urban and rural areas resulted in substantial increases in the supply of used oil available to the re-refiners, would these companies be able to market this oil?

Re-refined oil is used mainly in the production of industrial lubricating oils and gear box oils. While some re-refined oil is blended into automobile lube oils or sold as a re-refined product, consumer reluctance to accept re-refined oil, as well as the lingering misconception that re-refined oil is inferior, have hampered a major breakthrough into the potentially large automobile oil sector. Part of the difficulty stems from the high cost of providing Society of Automotive Engineers (SAE) testing required to satisfy warranty requirements on automobiles. Each testing costs between $50,000 and $60,000. Since used oil is re-refined in batches rather than as a continuous process, each batch requires this expensive testing. Re-refined oils compete directly with virgin oil stocks and these testing costs may raise the price for re-refined oil beyond the range where it can compete with virgin oil. Lower prices for virgin oil have also meant that the value of re-refined oil has dropped. But with current over-capacity among Canadian re-refiners, companies are competing among themselves to supply the limited demand for re-refined oil. Competing demands for used oil for road oiling, or as a fuel, have also driven up the price re-refiners must pay to obtain used oil. This increase in price for used oil should encourage increases in the supply, but the result is that because of low world oil prices, over-capacity in production facilities, and stiff competition, the re-refining business is in trouble (Cameron n.d.). Cameron doubts if new re-refining plants are making an adequate return on their investment. Perhaps as a result, re-refiners have recently reiterated requests for legislation to be enacted to prohibit the sale of used oil for heating and for road oiling (*Energy Analects* 1985).

Another concern is the 10 percent federal manufacturing tax on re-refined oil. Re-refiners contend that this is unfair since the tax has already been paid on the virgin oil. Cameron (n.d.) also suggests that the import tax on used lube oil should be eliminated to permit readier access to lube oil supplies from the United States and that the various levels of government should encourage the use of re-refined products. The former step might increase the availability of used oil at lesser cost than improved local recovery programs, while the latter step would increase the demand for used oil. Among these factors and others mentioned earlier lies a balance point between the amount of used oil that will be supplied at the price offered and the price that the re-refiners can afford to pay while still making sufficient profit.

The opportunity exists to expand the collection of used lube oil. The major questions to be answered are: how best to increase the recovery rate? What can be expected of industry and individuals and how can governments, both provincial and municipal, assist them? Is legislation restricting the use of used lube oil for road oiling or as a fuel required or desirable? Could public education achieve the same ends? What are the economic and environmental trade-offs; that is, are the potential improvements to environmental quality worth whatever costs are associated with increasing the proportion of used oil recovered? Answers to these and other questions are required in order to develop policies for future oil recycling.

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PLASTICS

1. THE RESOURCE

"Plastics" is a generic name referring to a very wide variety of materials. The most common building blocks for plastics are hydrocarbons produced by petrochemical industries, such as ethylene, benzene, butadiene, and propylene. These materials are combined with chemicals such as vinyl chloride, phenols, and acrylonitrile and other materials to produce plastic resins or polymers. Many of the specific characteristics of a plastic are determined by the incorporation of additives, including fillers, pigments, fire retardants, plasticizers, and stabilizers.

Modifications of the raw materials, additives, and processing methods allow plastics to be used in a myriad of applications. This diversity is the main reason for the growing use of plastics in all types of applications. According to Richards (n.d.) over 40 different major plastics are being used commercially in Canada. Canadian consumption of major plastics resins and materials is estimated to have totalled 1.29 million tonnes in 1983 (Stephenson and McGinnis 1985). However, only polyvinyl chloride and polyethylene resins are actually manufactured in Alberta (Staite and Radomski n.d.).

Plastics manufacturing requires a high energy input. According to information presented by Environment Canada (1984), the total energy inputs range from 71,300 kJ/kg to 205,000 kJ/kg depending on the plastic type. Total energy input includes the energy required to obtain the raw materials, processing, transportation, and fabrication of the final products. Because of the energy content of the hydrocarbons used as the basic building blocks, plastics also have a high internal energy content, ranging from 21,900 kJ/kg to 46,100 kJ/kg depending on the plastic (Curlee 1984). By comparison a kilogram of plains coal has an energy content of about 17,400 kJ (ERCB 1981) while a litre of oil has an energy content of about 30,000 kJ (Environment Canada 1984). Hence, recycling of plastics or the recovery of energy from plastics results in considerable energy conservation.

Plastics may be broken into two broad categories: thermoplastics and thermosetting resins or thermosets.

Thermoplastics

Thermoplastics are single-chain polymers that melt when heated and solidify when cooled. Thermoplastics, therefore, can be remelted and remolded for use in the same or

different products without major degradation in quality. In Alberta the most widely used thermoplastic resin is polyethylene. Other major types include: polyvinyl chloride, polystyrene, polypropylene, ABS (acrylonitrile butadiene styrene), and urethane (Staite and Radomski n.d.).

A variety of processes are used to convert plastic into final products. Common processes in Alberta include: extrusion, injection molding, fabrication, thermoforming, blow molding, vacuum forming, rotational molding, heat sealing, EPS molding, steam chest molding, and cellcast molding. In Alberta, the largest volume of production is in the extrusion of plastic products. Extrusion is used to produce products such as packaging films, pipe, and tape. The next most significant process is injection molding, which is used to make such items as display covers, duct spacers, flower pots and other containers, and custom products (Staite and Radomski n.d.).

Another important plastic is polyethylene terephthalate (PET). This plastic is hard, strong, tough, and has good chemical resistance. It is used in photographic films, magnetic tape, and packaging as well as for gears, bearings, pulleys, and fender extensions. It is also the plastic used to make non-refillable carbonated beverage containers.

Thermosetting Resins

Thermosetting resins consist of molecular chains that are cross-linked. This cross-linkage prevents thermosets from being melted and resolidified. Once solidified, a thermoset will not return to a liquid upon heating; thermosets, therefore, cannot be reused to produce similar plastic products. About 8 to 10 percent of the plastics used in Canada are thermosets (Richards n.d.).

Two important thermoset plastics are polyester (unsaturated) used for corrosion-resistant chemical containers, and polyurethane, in flexible or rigid foams, used for cushions, underlay, and rigid molded forms.

Quantities and Values

Information on the quantities and values of plastics produced or distributed within Alberta are not publicly available from Statistics Canada since the limited number of plastic manufacturers and processors in Alberta raises concern for the confidentiality of business information.

2. RECYCLING

Recycling Pathways

In a feasibility study for the United States Department of Energy, Curlee (1984) considered recycling of plastics as occurring at four levels. Primary recycling is the processing of waste plastics into products the same as or similar to those from which the waste was generated. Secondary recycling is the conversion of plastic waste into products with less demanding properties, that is, products that can tolerate mixed plastic wastes. The third

level is the recovery of either chemicals or fuels from plastic waste, and the fourth level is incineration of the plastics for recovery of the intrinsic energy. Within this hierarchy, scrap suitable for a higher use can be used at a lower recycling level but not vice versa; for example, level 2 scrap can be used for level 4 purposes, but level 4 scrap cannot be used for levels 3, 2, or 1 purposes. Thus, there is an advantage in using materials at the highest possible level since the possibility for again collecting and recycling waste exists, and the option always remains to choose a lower level in the hierarchy if the higher is not available.

An important classification of plastic waste separates what Curlee (1984) calls "scrap plastics" from "nuisance scrap." Scrap plastics are generated in the manufacturing or fabricating process. They are approximately equivalent to "prompt scrap" in the metal recycling industry. Nuisance scrap may be subdivided into two categories: manufacturing nuisance scrap and post-consumer scrap. Manufacturing nuisance scrap is scrap that is not recovered by the processor in a readily recyclable form. It includes off-specification or surplus materials from resin manufacturing plants and materials such as offcuts and trimmings from fabricating plants. Post-consumer scrap is generated through discarding products after use. Nuisance scrap would have a lower level of use in the recycling hierarchy than scrap plastics.

Primary Recycling

Plastic wastes that can be re-utilized to make the same or similar products are likely to be limited to scrap plastics. These products are clean and of known composition. Uncontaminated plastic waste, either as a single resin or as mixed resins, can be reused after cleaning, grinding, or pelletizing as a fraction of the feed mix for forming machines. This type of scrap is frequently recycled by the manufacturer or is sold to a scrap dealer who markets it to other manufacturers.

Secondary Recycling

The nuisance scrap fraction of the waste stream is the most likely source of untapped opportunities for recycling. Curlee (1984) identified four types of nuisance scrap that are being used or might be used in secondary recycling operations: post-consumer waste, for example, returnable containers; mixed plastic manufacturing wastes; plastic manufacturing waste of a single resin; and mixed plastic scrap collected as part of another operation, for example, plastic scrap collected by the auto recycling industry. Little, if any, of this waste would be suitable for primary recycling, since nuisance scrap is generally an aggregate of different kinds of plastics and is likely to be mixed with non-plastics. Products that might be produced through secondary recycling operations include toys, pails, plastic drums, fence posts, rain gutters, drain pipe, cable reels, skids, and many others. A common product made from nuisance scrap is garbage bags. Scrap low-density polyethylene is "over-blacked" to overcome different color compounds in a batch of plastics and then blown for use in black or dark green garbage bags (Resource Integration Systems Ltd. 1985a).

Even for secondary recycling, some sorting of the plastics available is required, but segregation and cleaning of different resins poses considerable difficulty. Several processes have been developed. These usually involve initial washing and grinding. Resin types may then

be segregated according to particle size, density, color, or other properties. Air separation may be used, but many plastics are aerodynamically similar to other materials, particularly paper. Some success has been achieved by heating to "pelletize" plastic waste followed by air separation from paper waste. Flotation processes use a variety of liquid media to separate plastic resins on the basis of density.

Third- and Fourth-Level Recycling: Recovery of Chemicals or Energy

The most common third-level recycling process is pyrolysis. Through destructive distillation, various chemicals may be extracted from plastic. These chemicals may be the original building blocks or products such as gasoline fuels, or fuel oil. Nuisance wastes from the manufacturing sector and post-consumer plastics are suitable for processing in this manner. The recovered chemicals or fuels are more valuable than the energy generated by incinerating plastics (fourth-level recycling) since the products are more versatile, concentrated, and transportable. The option of incineration is still available, however.

Present Use

Staite and Radomski (n.d.) undertook a study that looked at the use of plastic scrap generated by plastic product manufacturers in Alberta. The results were based on a response rate of 42 percent to questionnaires sent to firms manufacturing plastic resins and products (Table 10). The results provide an indication of the volume and fate of scrap plastics, not an exact accounting. In addition, the survey did not include scrap produced during the manufacturing of products from thermoset plastics.

The study found that most of the scrap (about 76 percent) was immediately fed into a grinder integrated with the injection molding equipment (often this was not considered to be scrap) or was stored and reground at a more convenient time. Of the remaining amount, most was sold for recycling, much of it outside of the province. Plastic scrap was sold to firms in Ontario, Quebec, British Columbia, and the United States, where it is combined with scrap from more heavily industrialized areas. Recycling operations in these areas are more economically viable because of returns to scale from larger throughputs. Some Alberta companies consolidate their scrap at branches of the company elsewhere in Canada or the United States where larger volumes of scrap are available. This may be preferred to the sale of scrap to competitors within the province (Staite and Radomski n.d.) as well as because of the advantages of return to scale.

A small amount of the plastic scrap produced in Alberta is landfilled. Of the plastics going to landfills, much cannot be recycled into other plastic products; however, some materials such as polyvinyl chloride and polyethylene could be recycled if a buyer could be found (Staite and Radomski n.d.). Firms with scrap acrylic, expanded polystyrene, and urethane reported that they did not know of methods to recycle those materials.

These results are in contrast to an Ontario study reported by Environment Canada (1984) that indicated that only about 33 percent of industrial scrap plastic was recycled at source and about 25 percent was sold as nuisance scrap to processors or scrap dealers. According to that study, 42 percent of the scrap plastics produced by the resin manufacturers and plastic products fabricators was landfilled. The difference in results may be due

Table 10. Amounts and Fate of Scrap Plastics Produced by Manufacturing Plastic Products in Alberta

Plastic Type	Amount of Scrap (kg)	Fate of Scrap Plastics: Recycled Inhouse (kg)	Sold (kg)	Landfilled (kg)
Polyethylene	1,300,800	1,017,300 (7)	266,800 (2)	16,700 (1)
ABS (acrylonitrile-butadiene-styrene)	21,000	6,700 (3)	14,000	300
Expanded Polystyrene	9,000	(1)	4,500	4,500
Polyvinyl Chloride	7,100	(1)	–	7,100
Urethane	5,000	500	–	4,500
Polyester	4,000	–	–	4,000
Acrylic	4,000	–	–	4,000 (2)
Polypropylene	1,000	(4)	–	1,000
Polycarbonate	800	(1)	–	800
Styrene	600	(3)	600	–
Polystyrene	400	–	300 (1)	100
Teflel	300	–	–	300
Teflon	100	–	–	100
Nylon	100	(1)	–	100
Norell	–	(1)	–	–
Acrylic/Polycarbonate	(1)	–	–	–
Total	1,354,200	1,024,500	286,200	43,500
Percent	100	76	21	3

Source: Staite and Radomski n.d. Based on questionnaire results with 42 percent response rate.

( ) Number of firms responding but not specifying volumes.

to differences in the nature of the fabricating industry in Alberta or the method of data collection. A more detailed determination of the fate of plastics scrap is required.

Municipal waste is potentially a large source of plastics. According to Environment Canada (1984), the percentage of plastics in the domestic waste stream ranges from 3 to 5 percent. Other waste composition studies done in Toronto and in Quebec City indicate that plastic wastes are increasing and may now constitute 7 to 10 percent of the waste stream (Stephenson and McGinnis 1985). The amount of plastics in the waste stream is likely to increase since plastics are predicted to make inroads into areas traditionally held by glass containers and other materials. For example, polyethylene terephthalate (PET) bottles are used for carbonated beverages and are being considered for beer, liquor, mouth wash, food, and other applications.

A 1979 report (Bird and Hale Ltd. et al. 1979) estimated that plastics compose 4.71 percent (plus or minus 0.52 percent) of the wet weight of municipal refuse generated in the Edmonton area. This plastics component was segregated into two fractions: containers (0.84 percent of the total) and sheet, film, and other (3.87 percent of the total). This refuse included waste from residences and commercial buildings and housekeeping waste from industries. These numbers have been used to estimate that approximately 84,800 tonnes of plastic waste are disposed of annually in Alberta through landfilling of municipal solid waste.

No facility in Alberta at present recycles or processes post-consumer waste plastic. But an area of unique importance to Alberta is the recovery of plastic non-refillable carbonated beverage containers. These containers are made of polyethylene terephthalate (PET). Because of the beverage container deposit and depot system in Alberta, the majority of PET beverage bottles sold in the province are recovered. The containers collected through the depot system eventually end up at Contain-A-Way.

The caps are removed and the plastic bottles are sorted by color; they are then baled into 340 kg bales and sold to a United States textile processor. At the textile plant the bottles are granulated and fed through an air cyclone separation system to remove paper. The granulated material is then gravity-separated to remove aluminum closures and high-density polyethylene (HDPE) base cups, washed in caustic to remove adhesives, and run through a water flotation system that separates the PET from the HDPE. The PET flake is fed into an extruder and converted into long strands which are chopped to pellets and used in the manufacture of polyester fiberfill for jackets and sleeping bags. About 20 two-litre PET bottles produce about one kilogram of fiberfill, enough to fill an average-size decorator pillow (*Resource Recycling* 1984). Other applications include strapping, extruded sheet and injection molded parts, and a geotextiles fabric used as erosion control mats or for road bed stabilization.

Between August 1 of 1983 and July 1 of 1984, Contain-A-Way recovered 12.5 million plastic bottles. The value of the recovered material was $224,610 (Taylor n.d.). According to Richards (n.d.), approximately 140,000 to 180,000 tonnes of scrap PET are supplied annually to the United States from Alberta and British Columbia. To establish an economically viable facility in Canada for processing PET scrap would require a supply estimated at 450,000 tonnes per year.

Richards (n.d.) provides another example that illustrates the recycling potential if clean, segregated plastic is available. A convenience store chain in Ontario markets milk in two-litre HDPE returnable, but non-refillable, jugs. To encourage return visits to the store, a deposit is required on the jug. The returned bottles are reground, washed, and sent to a processor. The end use of the plastic is for miscellaneous products such as key fobs, flower pots, watering cans, and drainage pipe. According to Richards (n.d.), the demand for this HDPE exceeds the supply.

3. PROBLEMS AND OPPORTUNITIES

The financial viability of plastic recycling is dependent on the purity of the wastes, cost of alternative disposal methods, cost of separation, availability and cost of processing equipment, quantity of wastes generated in a recycling operation and the cost of disposing of that waste, and the market value of the outputs. These factors in turn are affected by volume of supply, and transportation costs both for the material to the recycling facility and for the products to markets. Also, such technological innovations as increasing use of composite plastic containers (composed of more than one plastic type) or containers made from laminates with non-plastic materials inhibit plastics recycling. The economics of recycling are also influenced by the cost of the virgin materials the scrap will be replacing. Plastics costs are influenced by petroleum prices, which in turn are at the mercy of global events and the effects of import and export policies and other forms of government intervention.

Demand for plastic resins is high and apparently growing as the use of plastics spreads. The value of plastics has also increased markedly. Curlee (1984) reports that the producer price index for plastic resins in the United States increased from 92.1 in 1973 to 289.2 in 1981 (where 1967 equals 100) in line with energy price increases. This increase in demand and value has meant that there is a market for clean, single-resin plastic wastes and this is reflected in the present high levels of recycling of industrial scrap plastics.

According to Environment Canada (1984), demand for waste plastic exceeds current supply. In the past, this has resulted in competition for limited sources, which forced some recycling operations out of business. On the other hand, supply apparently exceeds demand in the United States. Removal of tariffs on scrap plastics could increase supply to Canada and help the recycling industry in this country (Environment Canada 1984). Alternatively, programs to recover greater proportions of Canadian scrap plastics would have a similar effect. Four general areas in which work is required in order to increase the recycling of plastics were identified by Resource Integration Systems Ltd. (1985b). These areas are: source separation, development and application of new technology, development of applications and markets for recovered plastics, and funding of recycling initiatives.

The situation for mixed plastic scrap is, however, quite different. Mixed plastics are useful in a limited range of applications – those that are not demanding in their specifications. The key to their use at present lies in the segregation of the plastic resins, usually through source separation.

However, source separation and recovery of plastics is hindered by problems of contamination, transportation costs, market availability, and lack of technology or facilities

to process the material. At-source recovery of domestic, commercial, and retail plastic waste may be hampered by lack of response, low volumes of plastics recovered, lack of cleanliness, and a high incidence of mixed plastics. Deposit systems have resulted in improved segregation and recovery of materials. A deposit on all plastic containers could increase the recovery of plastic scrap, but costs might be high unless it were associated with an already operational recovery system.

Recovery and recycling of consumer waste such as PET containers has occurred where deposit systems, curbside collection, or other techniques are used to encourage the return of a specific fraction of the plastic wastes. Environment Canada (1984) suggests that recycling of PET containers might be used to gain access to other kinds of plastic containers. To do this in Alberta would require reconsideration of the role of the existing bottle depot system or implementation of an alternative collection system.

Coding of the plastic materials by the manufacturers could improve separation by resin type, but agreement on a common set of standards has not yet been reached. An alternative, if a voluntary coding agreement is not forthcoming, would be a legislative requirement for standardized coding by a certain time. As a specific example, Resource Integration Systems Ltd. (1985a) state that coding either by symbol or by color would allow the recovery of cable coating from electrical cable stripping operations.

Richards (n.d.) suggests that a major constraint in plastic recycling is the lack of a closed-loop system. Only rarely is the reprocessor and user of plastic nuisance scrap the generator of the virgin scrap. Recycled plastics therefore are in direct competition with virgin materials on a day-to-day basis. If virgin materials have a long-term stability of supply while supplies of plastic scrap fluctuate, even much lower prices for scrap will not compensate for the inconvenience associated with a fluctuating supply. In some other recycling industries, for example, paper and ferrous metals, mills either have subsidiaries dependent entirely on scrap materials, or enter into long-term contracts for the supply of recycled materials which become part of the feedstock for production processes. Stability of supply has real economic advantages for the processor.

Some potential may exist to recover plastic waste where plastics separation can be promoted as part of an already operating system. For example, mixed plastic waste collected in auto recycling is currently landfilled. A detailed economic study is required to establish the potential.

Some part of the problems with trying to segregate mixed plastics and plastics from non-plastics could be overcome by identifying relatively high-grade waste streams. Curlee (1984) suggested that in the United States there was potential to recover relatively uncontaminated plastic waste through the recycling of transportation sector products, or electrical or electronic products.

Studies and experience elsewhere suggest that there are areas where plastics recovery from industrial users could be improved, although certain technical developments may be a prerequisite.

Much more information is needed to accurately assess the situation in Alberta. Staite and Radomski (n.d.) recommended gathering information on the volume of retail trade

waste and the feasibility of recovering such waste. Improved exchange of the available technical information as well as a greater awareness of sources of potentially recyclable material would also help. In early 1985, the Alberta Waste Materials Exchange began operation. The purpose of the Exchange is to provide a means whereby any available wastes may be confidentially listed and arrangements made to find customers with a use for this "waste." The operation of the Exchange should result in increased recycling of industrial scrap through the facilitation and improvement of information exchange.

> *The general opinion among experts is that once plastic waste goes into the municipal waste stream, the separation of plastics from other waste is very difficult, and the separation of specific plastic resins is not a viable alternative* (Curlee 1984: 5).

Opportunities for recycling of plastic municipal waste may be limited to the recovery of the energy value through energy-from-waste incineration projects. However, some persons consider such projects as discouraging future opportunities for reuse of materials. Concerns have also been expressed regarding the emission of pollutants when plastics are incinerated. Most of these concerns relate to incineration of polyvinyl chlorides (PVCs). Roumpf (1984) suggests that these concerns could be greatly reduced by banning the use of PVC plastics in one-time-use packaging.

Municipal waste generated in households and commercial and retail businesses remains an elusive source of recoverable plastics. The rough calculations done above suggest that there is as much as 84,800 tonnes of plastics per year in municipal waste in Alberta and that this amount is growing. The challenge is to develop effective and efficient mechanisms to recover this waste for reuse or for use of the energy content.

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PAPER

1. THE RESOURCE

During the five years from 1978 to 1982, Canadian production of paper and paperboard averaged 13.6 million tonnes per year (Pilsworth 1984). This output can be broadly divided into the following paper and paperboard products:

Paper Products:
- newsprint
- book and writing papers
- wrapping papers
- tissue papers
- building papers
- other

Paperboard Products:
- container board
  - (corrugating medium and linerboard)
- box board
- building board
- other

Approximately 80 percent of the total production was paper products with four-fifths of this category being newsprint. Twenty percent of the total production was paperboard products. Approximately two-thirds of the total production, or about 9 million tonnes per year, was exported and about one-third was used in Canada. The apparent domestic consumption in Canada or the average annual new supply of paper during the period from 1978 to 1982 was about 4.8 million tonnes (Pilsworth 1984). This is the annual production minus the net exports (exports minus imports). According to Pilsworth, consumption was approximately 175 kg of paper per capita in 1982. Canada ranked third behind the United States (250 kg/capita/year) and Sweden (202 kg/capita/year) in terms of paper consumption.

2. RECYCLING

Recycling Pathways

When one thinks of recycling paper, there is a tendency for newsprint to leap to mind. But "news," as it is called in the waste paper trade, is only one of several grades of paper that can be recovered and reused. There are a number of schemes for classifying paper recovered for recycling. The one used here is that of the Canadian Pulp and Paper Association. According to their classification, waste paper or secondary fiber, as it is called, is categorized as follows:

News
- printed, old and over-issue
- unprinted
- other ground wood

Mixed

Pulp Substitutes
- brown kraft
- bleached kraft
- printed bleached
- ledger
- other

Container
- old corrugated containers
- new corrugated cuttings

Boxboard

Within a hierarchy of recycling practices, three levels of recycling can be identified. The first and simplest use of secondary fiber is as a replacement for virgin fiber in the production of other paper and paperboard products. Paper can be recycled repeatedly; however, there is some breaking and degradation of the fiber during recycling and often virgin fiber is blended with secondary fiber in order to maintain product quality. Products that can contain secondary fiber range from writing paper, newspaper, and the fluted medium in corrugated board to molded paper products such as egg cartons and plant pots.

The next level in the hierarchy of recycling is the use of secondary fiber in products that are more amenable to the use of mixed or contaminated materials. These products frequently result in the paper fibers being altered or contaminated so that they are no longer recoverable as paper fiber. For example, paper is used in building products such as asphalt paper, felt, and shingles, and in cellulose insulation or animal bedding materials, but once used for these purposes the paper fiber can only be disposed of or incinerated.

The third level of recycling is the recovery and use of paper for its energy value. This might occur through its use as a fuel in energy-from-waste projects or in biomass energy projects.

Present Use

Recycling Nationally

Secondary paper fiber (news, mixed, pulp substitutes) and paperboard fiber (container, boxboard) may be made available to the user from two sources: plant wastes or post-consumer paper. Plant wastes result from manufacturing activities. This paper is usually free from contamination and of the same type. It is in high demand and receives premium prices, and it is likely that a high proportion is recovered and reused. Post-consumer paper, which would include items such as newspaper, corrugated containers, ledger paper, computer printouts and tab cards, and mixed papers, is secondary fiber derived from the consumption of final products, rather than from the processing of residuals. This post-consumer paper is often contaminated, frequently mixed, and available only in small lots.

It is not feasible to recover 100 percent of the paper produced. Some paper is non-recoverable because of the nature of the product. Non-recoverable products include such items as: books in libraries and archives; vegetable parchment; carbonizing tissue; household and sanitary papers; condensor, capacitor, and cable paper; cigarette paper; paper used in building products; blotting paper; filter paper; wallpaper; construction paper and paperboard; and wet machine boards (shoe, gasket, transformer, press textile, panel, beer mat, trunk and suitcase boards, and others). These losses, as well as losses resulting from other severe barriers to recycling, may amount to 40 percent. The potentially recoverable amount at a national level therefore approaches 60 percent of the new supply (Pilsworth 1984).

Recovery and recycling of paper is an active industry in Canada and in the world. Substantial import and export trade occurs in secondary fibers. Chandler (1984) estimates that the world trade in secondary fibers is about $100 million (U.S.) per year. Depending on location, some recycling operations are influenced as much by foreign supply and demand as by the local or regional situation.

The calculation of exact figures for domestic use of secondary fiber and import and export sales is hampered by the lack of a consistently applied grading system and the absence of a comprehensive data base. Information on waste paper demand was compiled by Pilsworth (1984) based on information provided by the Canadian Pulp and Paper Association (CPPA) regarding the use of waste paper by their members, and their estimation of use by non-members and by other industries. Information on imports and exports was gathered from the CPPA and Statistics Canada as well as the American Paper Institute. However, substantial discrepancies exist among information available from these sources. The data are presented here only for the purpose of illustration and should be viewed as providing general information that highlights paper recycling activity and not as a definitive statistical record. There are no provincial data compiled by any source.

Consumption of secondary fiber by the paper industry in Canada averaged about 1.15 million tonnes per year between 1978 and 1982 (Pilsworth 1984) (Table 11). Use of secondary fiber ranged from a low of 1,068,000 tonnes in 1978 to a high of 1.2 million tonnes in 1981. The utilization rate of secondary fiber over the period therefore averaged about 8 percent based on an average annual Canadian production of 13.6 million tonnes. Statistics on the demand for each particular grade of recycled paper are given in Table 11.

Demand by other industries and by non-CPPA industries would be in addition to the amounts identified in Table 11. Data provided to Pilsworth (1984) by the Department of Regional Industrial Expansion indicated that waste paper demand by all users averaged 1,412,000 tonnes per year (Table 12).

Demand for recycled paper was supplied in part by recycling of Canadian paper products and in part by imports. However, some of the paper recovered in Canada was exported. According to information presented in Table 13, recovery of all grades of paper was estimated nationally to have ranged from a low of 866,000 tonnes in 1978 to a high of 1,034,000 tonnes in 1981, averaging 958,000 tonnes per year. This estimate includes exports of recovered paper but not imports. Based on the apparent annual domestic consumption of 4.8 million tonnes per year, recovery rates averaged about 20 percent.

Table 11. Waste Paper Demand by the Canadian Pulp and Paper Industry

	1978	1979	1980	1981	1982	Average	Percent
				('000 tonnes)			
Container	572	610	665	683	601	626	55
News	119	150	151	149	157	145	13
Boxboard, cuttings	73	83	79	78	71	77	7
Mixed	74	74	60	59	60	65	6
Total pulp substitutes	213	224	217	221	240	223	20
Other Grades	17	13	11	10	10	12	1
Total All Grades	1,068	1,154	1,183	1,200	1,140	1,150	100

Source: Adapted from Pilsworth 1984

Notes: All totals reflect CPPA data. Actual demand will be marginally higher since the CPPA demand represents about 90 percent of total paper and paperboard industry.

Due to rounding, column totals do not necessarily match the total for all grades.

Table 12. Waste Paper Demand by All Users in Canada

	1978	1979	1980	1981	1982 (est.)	Average	Percent
			('000 tonnes)				
News	283	283	190	174	140	214	15
Container	861	925	939	961	884	914	65
Mixed	62	67	72	73	68	68	5
Pulp Substitutes	196	211	226	230	214	215	15
Total All Grades	1,403	1,486	1,427	1,437	1,305	1,412	100

Source : Adapted from Pilsworth 1984

Note: Due to rounding, column totals do not necessarily match the total for all grades.

Table 13. Waste Paper Recovered in Canada

	1978	1979	1980	1981	1982	Average	Percent
				('000 tonnes)			
News	177	194	170	145	149	167	18
Corrugated and Boxboard	496	543	623	654	576	578	61
Pulp Subs and Fine Paper	121	132	134	137	134	132	14
Mixed	70	77	79	79	79	77	8
Total All Grades	866	947	1,006	1,034	937	958	100

Source: Adapted from Pilsworth 1984

Note: Due to rounding, column totals do not necessarily match the total for all grades.

If recovery rates were to be calculated on the basis of a "potentially recoverable amount" of 60 percent of the new supply, recovery rates would be about 33 percent. This approach to calculating potentially recoverable resources and hence recovery ratios has some obvious difficulties and inaccuracies. However, some estimate of potentially recoverable quantities is essential to identify potential for the expansion of recycling, for measuring past performance, and to help set objectives. Some uniformity in the compilation of data at regional and national levels is necessary. In particular, estimates specific to each grade of paper are required in order to assess recycling programs. The CPPA has an important contribution to make in advising bodies like Statistics Canada and provincial statistical agencies on the forms of data most useful to the industry. Agreement on definitions is only the first step. The collection of accurate, reliable, and timely information for use by industry, government, and private recycling firms should follow.

To make up the difference between demand and supply within Canada, secondary fiber was imported, mainly from the United States. Between 1978 and 1982, imports of secondary fiber ranged from 628,000 tonnes valued at $69,705,000 (1982 $U.S.) in 1979 to a low of 416,000 tonnes valued at $48,285,000 (1982 $U.S.) in 1982 (Table 14). The United States was the most important supplier by far – in 1980, 1981, and 1982 all of Canada's recycled paper imports came from that country. The average percentage composition of imports, based on CPPA data, was as follows:

container grades	52 percent
pulp substitutes	33 percent
news	10 percent
boxboard	3 percent
mixed paper	2 percent

Most of this waste paper is purchased for use in Ontario and Quebec. Imports meet between 30 and 40 percent of the domestic demand on average.

Based on information provided to Pilsworth (1984) by the CPPA, grades that reflect a high import content relative to total domestic consumption are as follows:

unprinted news	65 percent
brown kraft	63 percent
printed bleached kraft	50 percent
bleached kraft	48 percent
ledger	46 percent
new corrugated cuttings	33 percent
old corrugated containers	28 percent

Printed news imports were about 10 percent of the domestic demand. These figures indicate paper grades in which increased recovery nationally might offset imports.

Canada also is becoming a player in the world trade in waste paper. Over the five years from 1978 to 1982, Canada's export of waste paper increased from 113,000 tonnes valued at $14.7 million in 1978 (1982 $U.S.) to 151,000 tonnes and $29.3 million in 1982 (1982 $U.S.). Our main trading partner was the United States, which received between 70

Table 14. Imports of Waste Paper

	1978	1979	1980	1981	1982	Average	Percent
				('000 tonnes)			
Container	291	293	279	283	233	276	52
News	74	71	42	38	40	53	10
Boxboard	22	25	17	18	9	18	3
Mixed	22	17	8	3	2	10	2
Pulp Subs	210	222	163	146	133	175	33
Total All Grades	618	628	510	489	416	532	100
				('000 dollars)			
Value	$ 49,057	$ 69,705	$ 64,491	$ 58,311	$ 48,285	$ 57,970	

Source: Adapted from Pilsworth 1984

Note: Due to rounding, column totals do not necessarily match the total for all grades.

and 80 percent of the waste paper exported over the period. Other important buyers were Thailand and Korea. Grade-specific data are not available, but based on American Paper Institute world export data (Pilsworth 1984), a possible breakdown of exported paper would be:

corrugated	35 percent
news	25 percent
mixed	25 percent
pulp substitutes	15 percent

The Alberta Situation

Paper is recovered through community paper drives, curbside pick-up, retail and manufacturing industry pick-up, and subsequent delivery to a dealer. There are several waste paper dealers in Alberta. These firms may buy directly from individuals, groups, or industries, organize and operate their own collection system, or purchase graded secondary fiber from another dealer.

Waste paper may be graded or separated at source, by an intermediary, or by the dealer. A higher price is offered for separated paper than for mixed grades. Perhaps contrary to public perception, news-grade paper is only one of a number of grades of paper recovered in Alberta and is not the most valuable. A recent price list shows the importance of segregating and grading (Table 15).

Substantial volumes of news-grade fiber are available from printing facilities as over runs, roll ends, misprints, and old news. Private citizens, either individually or collectively, also play an important part in recovering newspapers. Newspaper is collected though community group paper drives, or delivered by individuals to a recycler, or to an intermediary who subsequently sells to the paper stock dealer. Some bottle depots also have buy-back programs for paper. Foothills Conservation and Recycling of Calgary now has household pick-up in parts of Calgary (Ellacott n.d.). In these areas, strong plastic bags bearing the company logo are delivered to each household. Once per month, bags containing newspapers are to be left by the door for pick-up and replacement with empty bags. Community organizations assist with publicity, delivery of flyers, and posting of the area before pick-up. Foothills Conservation and Recycling supplies the bags and literature and does the actual pick-up. In return, the community organization receives a portion of the value of the paper collected. According to Ellacott (n.d.), this approach helps the community group without requiring it to get into the labor-intensive aspect of actual paper collection; it lends its status, prestige, and contacts to legitimize the collection. The more householders the community group can induce to support the scheme, the greater the return it obtains.

News-grade paper recycling has a high public profile because of the important role that the public, community groups, and volunteers play in its collection, but other grades are actively sought after by the recycling industry. Corrugated paper is usually obtained from manufacturers or from retail outlets such as supermarkets. This material may be baled at source (many supermarkets have balers), picked up in a compacting unit, or delivered loose. Corrugated paper is also received as a byproduct of the collection of other paper grades, which are often delivered in cartons. Ledger paper, computer paper, and tab cards

Table 15. Typical Paper Stock Prices

Grade	Alberta/ Saskatchewan ($ per ton)
1. Tab Cards	90–100
2. Computer Printout	100–110
3. Old Corrugated	30–40
4. Repacked News	25–35
5. Mixed Paper	5–10

Source: *Materials Recycling Markets* May 1985

Note: Prices do not reflect variances such as: freight allowances, spot loads, regular quantity shipments, etc. Prices are f.o.b. generators' plants.

(computer punch cards) are sought after and most recycling firms have developed processes for at-source collection of this paper. Recycling rates for these grades are gradually improving.

The collected paper is put to variety of uses. Allied Paper Savers in Edmonton supplies news-grade paper to its parent company, Canadian Cellulose Insulation Ltd. It sells other grades to building material manufacturers in Edmonton for use in asphalt paper, wallboard backing, and shingles or to other recycled paper users in the province. Paper is collected through purchase from groups, individuals, and businesses and through a system of permanent paper collection bins (Sculthorp n.d.).

Paper collected by Belkin Paperstock Ltd. in Edmonton or Calgary is sold primarily to Belkin Packaging in Burnaby, although some is sold to the Belkin mill in Toronto. Belkin Packaging uses a variety of grades in the manufacture of paperboard products such as liner board, boxboard, or corrugated (Kerr n.d.). Belkin Paperstock also purchases some grades of paper from the other dealers, imports some corrugated, and exports some news grade to the United States.

Foothills Conservation and Recycling obtains news grade through curbside collection in Calgary. Other grades of paper are also sought. Previously the news-grade paper was used

in cellulose insulation manufactured by Foothills Conservation and Recycling, or was sold for use in fireplace logs and other recycled materials. At present news-grade paper is exported to markets in the northwestern United States and other grades are sold into the local market (J. Ellacott 1985: pers. comm.).

I.G. Paper Recycling of Calgary supplies paper to local manufacturers of building products. News grade is purchased from individuals, groups, and businesses through a system of permanent bins or direct delivery. News grade combined with pulp is used in the manufacture of fiberboard sheathing and roof board insulation. Corrugated, news, and mixed grades are used in manufacturing roofing felts (M. Dupuis 1985: pers. comm.). Other grades and surplus tonnage are sold locally or to export markets. News grade also is used in Alberta as animal bedding material (Thomas n.d.).

3. PROBLEMS AND OPPORTUNITIES

Paper is recycled for a variety of reasons. A business will sort and bale its boxes and other containers because it reduces a waste disposal problem while generating revenue or at least reducing disposal costs. Office workers may sort and save their ledger or computer printouts or cards for the same reason – reduced disposal costs and potential revenue generation. But, as well, these workers are probably partially motivated by the realization that they are helping environmental conservation by reducing the demand for wood and energy.

Manufacturers and pulp mills, especially as distance from supplies of suitable virgin fibres increases, may use waste paper because it is less expensive than virgin pulp. There are 45 pulp and paper mills within 45 km of the Quebec City-Windsor corridor (Kuryllowicz 1984). For these mills, access to secondary fiber may be fully competitive with access to virgin fiber. However, secondary fiber use may be adversely affected by costs of transportation if mills are located near virgin supplies and distant from potential supplies of secondary fiber (as tends to be the case in Alberta and British Columbia).

Individuals are also concerned about the waste of a usable resource and can assist local community groups to raise funds through paper drives. Thus they can simultaneously help their group, a favored charity, and the wider environment.

Governments are interested in encouraging paper recycling partly in response to public concerns but also because paper may constitute a third or more of the municipal waste stream and efforts to reduce paper waste have the potential for benefits related to reduced collection costs. Removing paper from the waste stream also increases life expectancy of the landfill site. Sooner or later every municipality must face the difficult task of trying to site a new landfill. Extending the life of the present site is an attractive alternative.

However, the most critical aspect is that paper recycling can be an economically viable operation and warrants government support like any other industrial prospect that can generate jobs and income on a self-sufficient basis. Paper can be collected, sorted, and sold to the end user at less cost than the virgin fiber it replaces. Replacing some of the

virgin fiber with recycled fiber reduces product cost and makes an industry more competitive. It is for this reason that the demand for waste paper, particularly the higher grades, often comes from mills that also use virgin fiber. Depending on the product and the relative costs of secondary or virgin fiber, secondary fiber may be added in small amounts interchangeably with virgin fiber and with little equipment modification. In other mills, extensive equipment changes have been made to accommodate an increased proportion of secondary fiber. New mills have been built to permit the use of secondary fiber as a large fraction of the raw material needed. Ontario Paper Company in Ontario, for example, opened a new mill in 1983 that de-inks and uses about 90,000 tonnes per year of newspapers combined with virgin fiber (Allen 1984).

Pulp and paper companies are setting up subsidiaries for the specific purpose of collecting and supplying the parent company with recycled paper. This has proven to be a boon to recycling programs. These companies have a commitment to the use of secondary fiber and require a stable long-term supply of paper. Often they are prepared to guarantee a firm price and to guarantee purchase of the entire amount collected. This provides market and price stability for collectors, but has hurt the independent operators who previously purchased secondary fiber and sold it to the highest bidder.

Fluctuating supply and fluctuating price have hampered recycling efforts in many areas. Recyclers are well advised to ensure that there is a long-term market for the material before collection; dealers, however, may not commit themselves to purchase before the paper has been collected. Prices offered for waste paper fluctuate with the current price for virgin fiber, but are also affected by grade and import and export market situations. These price fluctuations and the uncertainty of supply and demand exacerbate the situation, making it difficult both for dealers and collectors. The long-term expansion of individual and community paper collecting is probably more influenced by fluctuations in demand than any other single factor.

The cyclic nature of the industry has tended to make paper recycling a risky business and many firms went bankrupt in the late 1970s. The involvement of the mills as purchasers, as well as the development of a more stable supply of paper through municipally supported curbside collection and the establishment of office and business collection systems, has helped to dampen the fluctuations. Nevertheless, paper recycling still is subject to supply and demand fluctuations. Some alternatives that can assist in reducing the fluctuations in the paper recovery cycle are discussed in the Environment Council report *Economic Barriers to Recycling* (Webb n.d.) and the reader can obtain further details on how demand might be stabilized in that report.

However, an important factor is whether fluctuations in demand or price are sufficiently critical to the future of paper recycling to warrant government incentives, or subsidies aimed at reducing their magnitude. Is the cycle of shortage and surplus just a fact of life that everyone, including community and volunteer groups, must learn to live with? An increase in user awareness and public education could result in an improvement in recycling rates beyond those being achieved by the recycling industries' efforts. Would such a public awareness and education program be warranted?

There are opportunities to either reduce the import of paper by replacing it with secondary fiber collected within the country or to increase the export of paper since world

demand is growing. A possible trend towards a reduction in imports may be due to development of an improved supply of secondary fiber in Canada. However, increased domestic consumption and international demand for the United States supply may also be limiting the easy access to United States paper (*Recoup* 1984). If this is so, demand for Canadian waste paper may be expected to increase. An increase in paper recycling in Canada should result in significant economic gains according to DPA Consulting Limited and Integrated Resource Recovery Group (1984). Kuryllowicz (1984: 26) contends that "altered attitudes by the populace and improved organization could definitely increase Canadian recycling and collection rates." But according to Resource Integration Systems Ltd. (1985), review and evaluation of current policies and programs, combined with ongoing monitoring of these programs, are steps that are necessary in order to improve paper recycling in Canada.

Collection schemes in Alberta must deal with our relatively small and dispersed population. Moreover, the major domestic market for secondary fiber exists in eastern Canada where the majority of mills are located. The situation in Alberta is complicated by the distance to markets and the lack of local demand for many waste paper grades. Perhaps Alberta should be tapping the demand for recycled paper from the Orient and the United States. Or we might increase regional or provincial demand through the establishment of a new recycling industry. Import information indicates that the greatest opportunity to substitute domestically supplied recycled paper is in grades such as unprinted news, kraft, ledger, and corrugated. There is a potential for new industry, although with the paucity of sound information, its viability is difficult to establish. More accurate information is essential for the development of policies respecting paper recycling. This is the main recommendation of Pilsworth (1984) and is reflected in the suggestion by organizers of paper recycling efforts that pilot studies should be done before anyone enters into full-scale paper recycling.

To date, incineration of domestic and commercial waste does not occur to a great extent in Alberta, although a municipal incinerator will soon be operating in Wainwright. There is also no energy-from-waste facility in Alberta. However, the impact that energy-from-waste plants might have on the supply of recycled paper should also be considered. Some United States municipalities have ordinances that attempt to designate the fate of wastes including waste paper. Would that be appropriate for Alberta? These are some of the questions that must be thought about and answered as Albertans strive to make best use of the potential resource offered by recycled paper.

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